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US Army Corps of Engineers
Waterways Experiment Station

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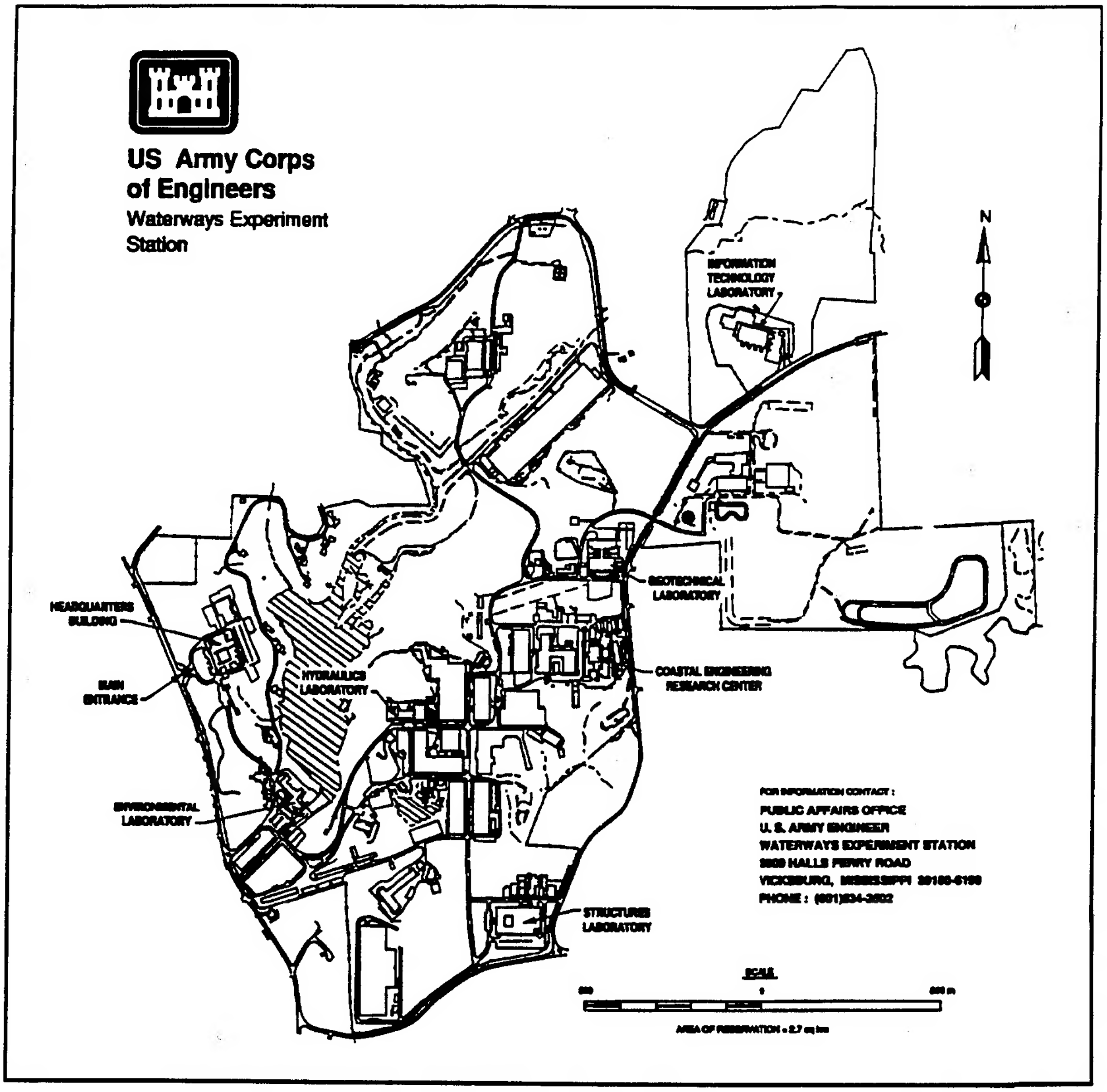

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Contents

Preface

The evaluation and comparison study reported herein was performed by the Hydraulics Laboratory (HL) of the U.S. Army Engineer Waterways Experiment Station (WES) during July through September 1994. The U.S. Army Engineer District, Vicksburg, requested WES to perform this work and to document all findings. The scope of this project consisted of comparing an Acoustic Doppler Current Profiler (ADCP) to standard discharge measurement techniques currently in practice on the Mississippi River. A comparison plan was developed to demonstrate both techniques for two flow conditions on the Mississippi River at five historically monitored ranges. WES collected the ADCP data, while a private contractor under contract with the District took the standard discharge data. Both sets of data and the comparison results are contained in this report.

The study was conducted under the direction of Messrs. Frank A. Herrmann, Jr., Director, HL; Richard A. Sager, Assistant Director, HL; and William H. McAnally, Jr., Chief, Waterways and Estuaries Division, HL. Project engineer for the study was Mr. Thad C. Pratt, Prototype and Field Studies Group, HL. Other personnel participating in the data collection were Messrs. Howard A. Benson and Christopher J. Callegan, also of the Prototype and Field Studies Group. Data reduction was performed by Mr. Pratt. This report was prepared by Mr. Pratt with assistance from Ms. Clara J. Coleman, Technical Support Group, HL.

Dr. Robert W. Whalin was Director of WES during the publication of this report. COL Bruce K. Howard, EN, was Commander.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
feet	0.3048	meters

1 Introduction

The Vicksburg District monitors multiple gaging stations along the Mississippi River using conventional methods. The records for these stations date back for many years giving the Corps an excellent understanding of how the river discharge reacts to spring thaws and large-scale storm events. These records provide the Corps with information to maintain and operate the navigable waterways along the Mississippi. As technology develops, the Corps is always eager to incorporate new technology into its operating plans, but not without extensive testing.

The Hydraulics Laboratory at the Waterways Experiment Station was contacted by the Vicksburg District to evaluate the present discharge measurement technique against a new technique using an Acoustic Doppler Current Profiler. A testing plan was developed to compare these two techniques over two different flow conditions. The focus of this report is to present the data from both exercises. describing how the two methods calculate discharge through a cross section and identifying possible sources of error.

2 Acoustic Doppler Current Meter Discharge Measurement Technique

An Acoustic Doppler Current Profiler (ADCP) is an instrument that uses acoustic transducers to measure the movement of water through a waterway. The principles of operation are based on the phenomena of doppler shift in signal frequency due to the motion of a second frame of reference, the water. The ADCP sends out an acoustic signal which reflects off the bottom. Since the water and the ADCP are moving independent of each other, the ADCP measures a shift in the signal frequency as it returns through the water column. Through a series of complicated processing algorithms, the frequency shift is related to the individual velocity vector components of the water. By tracking the boat's motion the ADCP is able to remove the boat's velocity component from the water velocity measurement. In addition to a velocity measurement, the ADCP also gives a bathymetry profile for the water column as the boat is moving along.

There are several different types of ADCPs which differ by frequency and size of transducers. The different frequencies allow you to operate in different water depth ranges with varying degrees of vertical resolution. Table 1 gives the various frequencies available, their operating ranges, their vertical resolution, and space between data points in the vertical. The different frequencies allow the user to collect data over a wide range of water depths.

An ADCP has the ability to incorporate data from a Global Positioning System (GPS) in the data collection process to remove the boat's motion from the velocity measurement. The user has an option of referencing the bottom track or GPS data to remove the boat's motion. If the ADCP cannot track the bottom, it cannot calculate a discharge for the cross section. The bottom tracking feature provides the bathymetry information to define the cross-sectional area for the discharge calculation. The GPS navigational data can provide the data to remove the boat's motion from the velocity measurement, but an external data set from a fathometer will have to provide the data for the bottom bathymetry. The two data sets will then be post-processed to make a discharge measurement. This will be the only option available for discharge measurements when the flows are too high for bottom tracking to be effective.

The physical phenomena that causes loss of bottom tracking is movable bed material. When the water velocities increase to the point where a layer of sand or mud starts to move across the bottom in sheets or waves, then the ADCP has trouble distinguishing between the channel bottom and the first good water layer in the vertical. There are several ways to compensate for this problem. One method is to increase the power of the signal to punch through this sheet or wave of sediment to the hard bottom. This requires using a lower-frequency transducer which can be accomplished by switching the head of the transducer or using a completely separate ADCP. Another option is to adjust some of the operating parameters from their standard default values to improve bottom tracking. This method should only be used for minor bottom tracking problems. The final option is to collect a second data set of the bathymetry while using GPS data to remove the boat's motion from the velocity calculation. In a post-processing mode the two data sets can be combined to make a discharge calculation.

A discharge measurement using the ADCP is accomplished by traversing the river or stream at a given cross-section. The bathymetry profile coupled with the water velocity data enables the ADCP to update the discharge calculation as the boat moves across the waterway. For a more detailed explanation of how the TRANSECT software makes the discharge calculation, Appendix F of the "User's Manual for the RD INSTRUMENTS TRANSECT PROGRAM"[1] has been included as Appendix A to this report.

[1] RD Instruments. (1992). "User's Manual for the RD INSTRUMENTS TRANSECT PROGRAM," RD Instruments, San Diego, CA, Appendix F.

3 Current Meter Discharge Measurement Technique

The Corp presently uses the current meter discharge measurement technique[1] on established discharge ranges on large rivers and streams. It consists of summing individual discharge calculations across the discharge range. The partial discharge is calculated by the product of an average velocity measurement and an average area.

$$Q = \Sigma(\alpha v) \qquad \text{(Eq. 1)}$$

Q represents the total discharge for the cross section, a is an individual partial cross-section area and v is the corresponding average velocity normal to the partial area.

The partial area is that of a rectangle, with a width one-half way between the observation point before and after the current observation point and a depth equal to that of the current observation point. The average velocity is taken at 4/10-depth of the water column for a predetermined averaging period.

Figure 1 is a graphical representation of the river cross section. The cross section is defined by depths at locations 1, 2, 3, 4, 5...........n. At each location the velocities are measured to give a representative average for the entire water column. The partial discharge for any partial section can be calculated at any location x by

$$Q_x = V_x \left\{ \frac{(b_x - b_{(x-1)})}{2} + \frac{(b_{(x+1)} - b_x)}{2} \right\} d_x$$

[1] Thomas J. Buchanan and William P. Somers. (1969). "Discharge measurements at Gaging Stations." Techniques of water-resources investigations of the United States Geological Survey, Book 3, Chapter A8, U.S. Government Printing Office, Washington, DC. 1-5.

$$Q_x = V_x \left\{ \frac{b_{(x+1)} - b_{(x-1)}}{2} \right\} d_x \qquad \text{(Eq. 2)}$$

where

Q_x = discharge through the partial section x,
V_x = mean velocity at location x,
b_x = distance from initial point to location,
$b_{(x-1)}$ = distance from the initial point to preceding location,
$b_{(x+1)}$ = distance from the initial point to next location,
d_x = depth of water at location x.

The discharge through partial section 4 (heavily outlined in Figure 1) is

$$Q_4 = V_4 \left\{ \frac{b_5 + b_3}{2} \right\} d_4$$

When x is at the beginning or end of the cross section, then equations 3 or 4 are used to calculate the partial discharge.

$$Q_1 = V_1 \left\{ \frac{b_2 - b_1}{2} \right\} d_1 \qquad \text{(Eq. 3)}$$

$$Q_n = V_n \left\{ \frac{b_n - b_{(n-1)}}{2} \right\} d_n \qquad \text{(Eq. 4)}$$

Figure 1 gives an example of a possible cross section; d_1 is zero because the depth at the observation point 1 is zero. When the cross-section boundary is a vertical line at the edge of the water as shown at location n, the depth is not zero and the velocity at the end section may or may not be equal to zero. Equations 3 and 4 are used whenever there is water only on one side of an observation point such as piers, abutments, and islands. It is usually

necessary to estimate the velocity at an end section because it normally is impossible to measure the velocity accurately with the current meter close to a boundary. The summation of the discharges for all the partial sections is the total discharge of the stream.

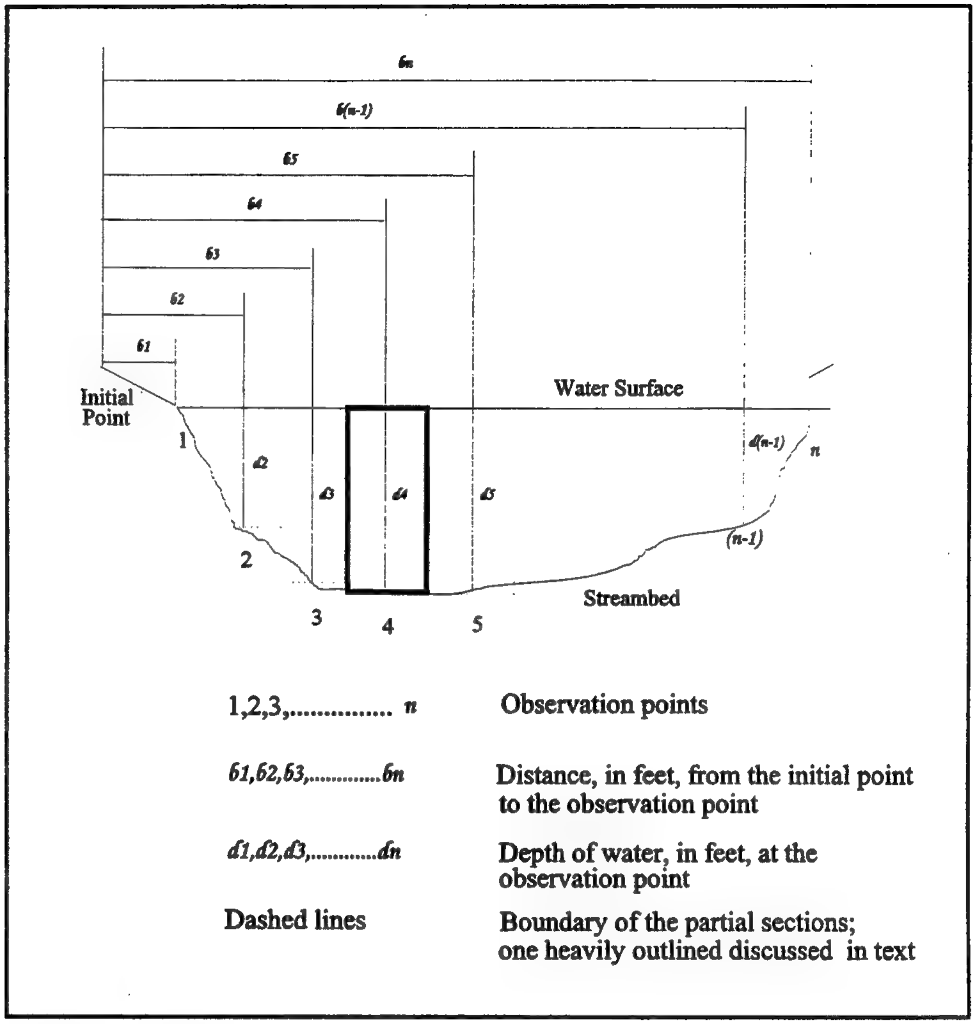

Figure 1. Graphical representation of river cross section

4 Comparison Plan for the Two Discharge Methods

This study was designed to compare discharge data from the same discharge ranges, at the same time using two different methods. The purpose of this effort was to show the difference and precision of the two techniques. This study does not address the accuracy of the two methods because the collection sites were natural sites with too many uncontrollable factors. (Accuracy refers to the ability to measure an absolute known value while precision is the ability to repeat the measurement regardless of the accuracy. In order to demonstrate accuracy of the two methods, a controlled flume test with a known discharge would have to be conducted.) The difference between the two methods was calculated by subtracting the mean standard method from the mean ADCP Method. Then the percentage that the difference represents for the individual means was calculated. The data and statistics are presented in Tables 2-11.

The collection effort was staged during two different flow conditions, approximately 500,000 cfs and 250,000 cfs. We chose to collect data for these flows to see if there were any significant changes in the difference and precision of the two techniques. The boat operating conditions were different for the two flow conditions. We gained insight to the problems associated with making discharge measurements on the river under various flow scenarios.

By comparing the two methods in the field, we have been able to identify possible sources of error in both techniques. These errors need to be further addressed and solutions found in order to improve both techniques.

5 Data from ADCP Discharge Measurement Technique

The ADCP data were collected at the same time as the current meter method data. The files were processed using TRANSECT software in the Playback menu option in order to take advantage of the estimating capabilities of the software. The estimating function of the TRANSECT software can only be utilized in the Playback menu. In the event that the boat is unable to reach the shoreline because of shallow water or some other obstruction, the user can specify the distance from starting and ending points of the transect line to the respective shoreline when reprocessing. The software uses the last several good ensembles of data and extrapolates a linear fit to water's edge.

Discharge data were collected at four discharge ranges, with one range being repeated on the fifth day of collection. This sequence of field monitoring was repeated for a mean and low- flow condition. The data from the two collection efforts are shown in Tables 2-11.

6 Data from the Current Meter Technique

The current meter data were collected at the same time as the ADCP data. The contractor under Vicksburg District supervision collected three data sets at each range. No further processing was done to these data after the contractor provided the boat sheets to the district. The discharge data collected by the contractor are presented in Tables 12-38. The total values for discharge were used to perform simple statistics on both data sets which are presented in Tables 2-11.

7 Sources of Error for Both Techniques

Both methods have proven to be repeatable in discharge measurements, but what causes the difference between the two methods? There are two types of error associated with each method--user error and sampling error. User error is the only type of error that can be addressed with the present data set. To identify sampling errors, a further study would have to be conducted to quantify method accuracy.

What is user error? User error is any type of error associated with the setup or use of the equipment.

Standard Method User Errors

1. Adjustment of the bearings on the Price Meter
2. Boat operation while collecting data
3. Positioning error at collection points
4. Data recording
5. Math errors in making the discharge calculation
6. Directional errors

ADCP Method User Errors

1. Instrument setup before operation
2. Boat operation
3. Bottom tracking

Standard Method

The Standard Method uses a Price Meter to measure water flow magnitude not direction. These meters require maintenance and calibration to operate correctly. The bearing on the rotating cups has to be adjusted and kept clean from debris in order to turn freely. If the bearing is too tight, the threshold velocity will be higher than when properly adjusted; and if the bearing is too loose, the meter will wobble and turn slower than it should. Bearing

adjustment is critical for proper operation. If improper adjustment causes the velocity measurement to be off .1 foot per second with the cross-sectional areas measured during these tests, the discharge could vary ± 10,000 cfs for the larger cross sections and ± 5000 cfs for the smaller cross sections.

Boat operation is another significant source of error for this technique. The boat has to maintain position in the flow while the timed measurement is being made. The operator uses two posts on each side of the river to line up with while maintaining position. As the distance from the shoreline increases, the error in this type of system becomes larger. The operator cannot detect small displacements from the measurement position until the total displacement exceeds a measurable value. With all of these factors weighing against the operator, it is almost impossible to maintain a steady platform throughout the measurement period. The boat is either drifting slightly ahead or behind the point of data collection. This drift could be as high as .1 foot per second and go undetected by the operators causing a difference of ± 10,000 cfs for the larger cross sections and ± 5,000 cfs for the smaller cross sections.

Positioning, data recording, and computational errors can vary based on the operators attention to details. For very careful operators, this source of error could be minimized, but it will always be a human factor which is variable.

The Standard Method has no way to account for velocity directional variations on the measured cross section. The bed geometry plays a significant part in establishing flow fields. Large- and small-scale eddies move along the shoreline because of the bed geometry. It was noted during data collection that the direction of flow could even flow upriver. This method uses the entire flow magnitude to calculate discharge rather than the component perpendicular to the cross section. On some sections of the cross section, the net discharge for that small section should be subtracted from rather than added to the total discharge. On large-scale rivers, like the Mississippi, the location of gaging ranges is very critical because of the directional limitations of the Standard Method.

ADCP Method

The ADCP Method requires an experienced operator to setup and use the equipment. Parameter settings can greatly affect the data quality from the instrument. Sensitivity studies on how much each parameter affects the instrument operation have not been conducted. With a proper quality assurance plan, the parameter settings can be defined for different measurement scenarios.

The ADCP Method works on the assumption that the instrument can track the boat's motion over the bottom while recording a bathymetry profile. TRANSECT software marks the bad data when bottom tracking is lost, so the operator can make a decision about rerunning the line. One section of data in a deep swift river can represent a significant portion of the discharge. When

bottom tracking was lost during the field tests, the total discharge could be 10-20 percent lower than the mean discharge of the previous measurements.

Three factors affect bottom tracking--bed geometry, boat speed, and bed-load transport. The geometry of the bed can cause a loss in bottom tracking if the bottom drops off or rises up with a very steep angle. The only recourse for this type of situation is to slow the boat down on the approach to the bed form or move the discharge range to a more suitable location. Boat speed affects bottom tracking, but there is not an optimum speed for all discharge measurements sites. The one rule that fits the best for this problem is to move across the cross section as slow as possible maintaining navigation control. The data are recorded on a set time interval so the less distance traveled in that time interval means more data points in a cross section. More data points improve the total discharge measurement. Bed-load transport is the hardest problem to overcome. In swift rivers where sand and silt travel along the bottom, the ADCP has trouble identifying the bottom signal. The operator can adjust some of the operating parameters when this problem occurs, but if these adjustments do not improve tracking, the only choices are to use a lower-frequency transducer or collect bathymetry data with a separate logging system and reference navigational GPS data to account for the boat's motion. In a post-processing calculation, the two data sets would be merged to calculate a resulting discharge.

8 Conclusions

The data presented in Tables 2-11 show that the discharge measurements using the ADCP Method varied less about the mean for that method. In the cases where only one or two discharge measurements were made using the Standard Method, a variance for the Standard Method could not be accurately calculated. The ADCP Method measurements varied a maximum of 1.25% of the mean but usually the variance was between .5 and .75 percent. The Standard Method measurements varied a maximum of 2.0 percent from the mean with the average between 1.2 and 1.5 percent.

A significant portion of the difference in the two methods can be attributed to the user errors stated in the previous section. The Mean ADCP Method appears to be lower than the Means of the Standard Method in most field comparisons. The Means of the ADCP Method were higher than the Means of the Standard Method when the boat operator drifted with the flow rather than engaging the engines during the collection period. This was noted in the field notes for the Chicot and Natchez ranges. On both days that data were collected on these ranges, the operator of the boat was different from the operator on all the other collection days. The data collected using the ADCP Method were greater than the Standard Method as noted in Tables 5 and 8. Maintaining a steady platform for the Standard Method measurement is the cause of this difference. The different boat operators had different approaches to maintaining position at the measurement site. One operator would pull up to the site while the other drifted back through the site. The drifting boat removed a portion of the velocity measurement, therefore reducing the total discharge calculation. GPS positioning linked with a navigation package would reduce the movement of the boat during the collection period.

The solution to collecting and maintaining an accurate data set for discharge ranges is to develop Quality Assurance Plans and Standard Operating Procedures. These plans will maintain consistency and minimize user errors in the collection process. A plan of action also needs to be developed for operation in high flows where bottom tracking becomes a problem. Discharges will have to be calculated in a post-processing mode where a bathymetry data set is coupled with the ADCP velocity data. The motion of the boat will be accounted for by referencing the ADCP data to GPS navigation position data.

Additional software that needs to be developed will address the problem of loosing one ensemble of data in the cross-section. Sometimes bed geometry makes it impossible to collect data on a vertical bank. A software solution to this problem would use the data on either side of the lost ensemble to fill in the lost data. This would address bed geometry problems and allow discharges to be corrected in a post-processing mode.

The ADCP Method should enable the district to collect more consistent data with less user error once a SOP is developed for the discharge program. The additional data processing options for the increased data set provided with the ADCP Method will enable the district to make better engineering decisions about the Mississippi River and its operation.

Table 1
Types of ADCPs with Some of Their Operational Characteristics

Frequencies of Transducers	Operating Depth Range Meters	Minimum Bin Size Meters	Bottom Estimate Meters	Top Estimate Meters
2400 KHz	10	0.12	0.3	0.3
1200 KHz	30	0.25	0.5	0.5
600 KHz	100	0.50	1.0	1.0
300 KHz	130	1.00	2.0	2.0
150 KHz	230	2.00	4.0	4.0
75 KHz	410	4.00	8.0	8.0

Table 2
ADCP Discharge Data on the Vicksburg Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Jul 11, 1994	1	2687	2625	503922
Jul 11, 1994	2	2688	2633	505702
Jul 11, 1994	3	2686	2639	500915
Jul 11, 1994	4	2754	2644	505119
Jul 11, 1994	5	2805	2667	503656
Jul 11, 1994	6	2757	2660	506428
Jul 11, 1994	7	2776	2671	498509
Jul 11, 1994	8	2754	2690	503268
Jul 11, 1994	9*	2741	2658	491939
Jul 11, 1994	10	2725	2657	497501
Standard deviation of measurements			19.49	3146.7
Mean of ADCP method measurements			2654.4	502780.6
Percentage of the mean that the standard deviation represents			.734%	.625%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Jul 11, 1994	1		2710	526870
Jul 11, 1994	2		2710	535245
Jul 11, 1994	3		2710	522146
Standard deviation of measurements				6633.76
Mean of standard method measurements				528087
Percentage of the mean that the standard deviation represents				1.26%
Difference of mean discharges (ADCP Method - Standard Method)				-25307
Percentage of the method means that the difference represents			ADCP Method	5.03%
			Standard	4.79%

* Some data were lost on the cross section

Table 3
ADCP Discharge Data on the Natchez Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Jul 12, 1994	1	2842	2794	512346
Jul 12, 1994	2	2884	2807	508610
Jul 12, 1994	3	2851	2798	507101
Jul 12, 1994	4	2849	2790	517517
Jul 12, 1994	5	2843	2800	518188
Jul 12, 1994	6	2848	2789	510710
Jul 12, 1994	7	2861	2784	501887
Jul 12, 1994	8	2876	2798	507623
Jul 12, 1994	9	2931	2806	504965
Jul 12, 1994	10	2847	2786	511322
Standard deviation of measurements			7.96	5147.3
Mean of ADCP method measurements			2795,2	510026.9
Percentage of the mean that the standard deviation represents			0.27%	1.00%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Jul 12 1994	1		2874	534245
Jul 12, 1994	2		2874	515197
Jul 12, 1994	3		2874	534245
Standard deviation of measurements				10997
Mean of standard method measurements				527895.7
Percentage of the mean that the standard deviation represents				2.08%
Difference of mean discharges (ADCP Method - Standard Method)				-17868.8
Percentage of the method means that the difference represents			ADCP Method	3.50%
			Standard	3.38%

Table 4
ADCP Discharge Data on the Grand Gulf-Kempe Bend Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Jul 13, 1994	1	5367	5279	464691
Jul 13, 1994	2	5457	5299	467459
Jul 13, 1994	3	5411	5311	462104
Jul 13, 1994	4	5408	5303	459282
Jul 13, 1994	5	5511	5316	458964
Jul 13, 1994	6	5441	5321	464559
Jul 13, 1994	7	5482	5301	451080
Jul 13, 1994	8	5464	5304	461161
Jul 13, 1994	9	5380	5285	456593
Jul 13, 1994	10	5499	5304	443645
Standard deviation of measurements			31.15	3585.0
Mean of ADCP method measurements			5292.3	461851.6
Percentage of the mean that the standard deviation represents			0.67%	0.78%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Jul 13, 1994	1		5388	494143
Jul 13, 1994	2		5388	504693
Jul 13, 1994	3		5388	500907
Standard deviation of measurements				5344.2
Mean of standard method measurements				499914.3
Percentage of the mean that the standard deviation represents				1.07%
Difference of mean discharges (ADCP Method - Standard Method)				-38062.7
Percentage of the method means that the difference represents			ADCP Method	8.24%
			Standard	7.61%

* Some data were lost on the cross section

Table 5
ADCP Discharge Data on the Chicot Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Jul 14, 1994	1	2945	2911	429212
Jul 14, 1994	2	2957	2903	425371
Jul 14, 1994	3	2922	2822	426260
Jul 14, 1994	4	2908	2847	428157
Jul 14, 1994	5	2896	2838	426807
Jul 14, 1994	6	2931	2858	428859
Jul 14, 1994	7	2933	2861	432886
Jul 14, 1994	8	2927	2851	439166
Jul 14, 1994	9	2903	2850	426793
Jul 14, 1994	10	2906	2856	431149
Standard deviation of measurements			27.38	4110.0
Mean of ADCP method measurements			2859.7	429466
Percentage of the mean that the standard deviation represents			0.96%	0.96%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Jul 14, 1994	1		2914	409097
Jul 14, 1994	2		2914	415038
Jul 14, 1994	3		2914	410178
Standard deviation of measurements				3164.48
Mean of standard method measurements				411437.7
Percentage of the mean that the standard deviation represents				0.77%
Difference of mean discharges (ADCP Method - Standard Method)				18028.3
Percentage of the method means that the difference represents			ADCP Method	4.20%
			Standard	4.38%

Table 6
ADCP Discharge Data on the Vicksburg Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Jul 15, 1994	1	2581	2492	456883
Jul 15, 1994	2	2577	2471	444848
Jul 15, 1994	3	2622	2513	449096
Jul 15, 1994	4	2592	2504	455911
Jul 15, 1994	5	2612	2524	455221
Jul 15, 1994	6	2616	2528	452352
Jul 15, 1994	7	2607	2513	453573
Jul 15, 1994	8	2578	2507	448193
Jul 15, 1994	9	2603	2505	451752
Jul 15, 1994	10	2600	2513	451988
Standard deviation of measurements			16.23	3745.3
Mean of ADCP method measurements			2507	451981.7
Percentage of the mean that the standard deviation represents			0.65%	0.82%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Jul 15, 1994	1		2678	471127
Jul 15, 1994	2		2678	469147
Jul 15, 1994	3		2678	453150
Standard deviation of measurements				2001.5
Mean of standard method measurements				471141.3
Percentage of the mean that the standard deviation represents				0.42%
Difference of mean discharges (ADCP Method - Standard Method)				-19159.6
Percentage of the method means that the difference represents			ADCP Method	4.23%
			Standard	4.06%

Table 7
ADCP Discharge Data on the Vicksburg Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Sep 19, 1994	1	2048	1998	254494
Sep 19, 1994	2	2068	2025	260393
Sep 19, 1994	3	2117	2097	256447
Sep 19, 1994	4	2101	2072	256003
Sep 19, 1994	5	2075	2043	259188
Sep 19, 1994	6	2057	2036	257120
Sep 19, 1994	7	2115	2041	261795
Sep 19, 1994	8	2147	2093	258083
Sep 19, 1994	9	2119	2081	257260
Sep 19, 1994	10	2104	2067	256611
Standard deviation of measurements			31.91	2180.9
Mean of ADCP method measurements			2055.3	257739.4
Percentage of the mean that the standard deviation represents			1.55%	0.84%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Sep 19, 1994	1		2234	283270
Sep 19, 1994	2		2234	281600
Sep 19, 1994	3			
Standard deviation of measurements				1180.86
Mean of standard method measurements				282435
Percentage of the mean that the standard deviation represents				0.41%
Difference of mean discharges (ADCP Method - Standard Method)				-24695.6
Percentage of the method means that the difference represents			ADCP Method	9.58%
			Standard	8.74%

Table 8
ADCP Discharge Data on the Natchez Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Sep 20, 1994	1	2760	2723	272144
Sep 20, 1994	2	2771	2725	271658
Sep 20, 1994	3	2743	2705	270884
Sep 20, 1994	4	2749	2729	272353
Sep 20, 1994	5	2737	2703	270579
Sep 20, 1994	6	2765	2724	271808
Sep 20, 1994	7	2759	2718	272126
Sep 20, 1994	8	2734	2704	270611
Sep 20, 1994	9	2756	2727	272785
Sep 20, 1994	10	2773	2727	271258
Standard deviation of measurements			10.43	762.77
Mean of ADCP method measurements			2718.5	271620.6
Percentage of the mean that the standard deviation represents			0.38%	0.28%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Sep 20, 1994	1		2788	270007
Sep 20, 1994	2		2788	267787
Sep 20, 1994	3			
Standard deviation of measurements				1569.77
Mean of standard method measurements				268897
Percentage of the mean that the standard deviation represents				0.58%
Difference of mean discharges (ADCP Method - Standard Method)				2723.6
Percentage of the method means that the difference represents			ADCP Method	1.00
			Standard	1.01%

Table 9
ADCP Discharge Data on the Grand Gulf-Kempe Bend Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Sep 21, 1994	1	2083	2041	240468
Sep 21, 1994	2	2138	2073	246464
Sep 21, 1994	3	2104	2055	240715
Sep 21, 1994	4	2138	2069	238617
Sep 21, 1994	5	2119	2078	243221
Sep 21, 1994	6	2148	2096	246042
Sep 21, 1994	7	2084	2044	239550
Sep 21, 1994	8	2128	2076	245615
Sep 21, 1994	9	2115	2085	241009
Sep 21, 1994	10	1932	1889	243203
Standard deviation of measurements			10.43	2834.2
Mean of ADCP method measurements			2718.5	242490.4
Percentage of the mean that the standard deviation represents			0.38%	1.17%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Sep 21, 1994	1		2220	262307
Sep 21, 1994	2		2220	264399
Sep 21, 1994	3			
Standard deviation of measurements				1479.26
Mean of standard method measurements				263353
Percentage of the mean that the standard deviation represents				0.56%
Difference of mean discharges (ADCP Method - Standard Method)				-20862.6
Percentage of the method means that the difference represents			ADCP Method	8.60%
			Standard	7.92%

Table 10
ADCP Discharge Data on the Chicot Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Sep 29, 1994	1	2809	2794	236675
Sep 29, 1994	2	2793	2783	236790
Sep 29, 1994	3	2796	2773	240504
Sep 29, 1994	4	2808	2791	236753
Sep 29, 1994	5	2799	2783	236314
Sep 29, 1994	6	2828	2791	235972
Sep 29, 1994	7	2773	2789	237100
Sep 29, 1994	8	2796	2667	236470
Sep 29, 1994	9	2794	2776	236203
Sep 29, 1994	10	2797	2768	237359
Standard deviation of measurements			37.7	1293.96
Mean of ADCP method measurements			2771.5	237014
Percentage of the mean that the standard deviation represents			1.36%	0.54%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	River Discharge cu ft/sec
Sep 29, 1994	1		2826	248438
Sep 29, 1994	2		2826	243870
Sep 29, 1994	3		2826	246531
Standard deviation of measurements				2294.34
Mean of standard method measurements				246279.7
Percentage of the mean that the standard deviation represents				0.93%
Difference of mean discharges (ADCP Method - Standard Method)				-9265.7
Percentage of the method means that the difference represents			ADCP Method	3.91%
			Standard	3.76%

Table 11
ADCP Discharge Data on the Vicksburg Discharge Range

Date	Transect Number	Length of Transect ft	Course Made Good ft	River Discharge cu ft/sec
Sep 23, 1994	1	2088	2051	252845
Sep 23, 1994	2	2094	2035	252234
Sep 23, 1994	3	2088	2055	245334
Sep 23, 1994	4	2076	2054	240640
Sep 23, 1994	5	2103	2041	245002
Sep 23, 1994	6	2073	2036	248952
Sep 23, 1994	7	2081	2050	245581
Sep 23, 1994	8	2105	2058	252723
Sep 23, 1994	9	2090	2053	247079
Sep 23, 1994	10	2103	2067	246096
Standard deviation of measurements			10.03	3342.7
Mean of ADCP method measurements			2050	248427.3
Percentage of the mean that the standard deviation represents			0.49%	1.34%
Discharge Data From the Standard Collection Methods				
			Cross-section Length	**River Discharge cu ft/sec**
Sep 29, 1994	1		2202	253450
Sep 29, 1994	2		2202	254595
Sep 29, 1994	3		2202	254994
Standard deviation of measurements				801.47
Mean of standard method measurements				254346.3
Percentage of the mean that the standard deviation represents				0.32%
Difference of mean discharges (ADCP Method - Standard Method)				-5919
Percentage of the method means that the difference represents			ADCP Method	2.38%
			Standard	2.32%

Table 12
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.998	600	183	6.3	2.5	302	300	2.21	2.06	2.06	1,153	2,375
.999	800	200	10.0	4.0	420	300	3.07	2.8	2.8	2,000	5,740
.999	1000	200	14.4	5.8	500	300	3.65	3.41	3.41	2,880	9.821
1.00	1200	200	24.0	9.6	482	300	3.52	3.28	328	4,799	15,682
1.00	1400	150	31.5	12.6	614	300	4.47	4.17	4.17	4,725	19,703
1.00	1500	100	37.2	14.9	650	300	4.73	4.42	4.42	3,720	16,442
1.00	1600	100	38.1	15.2	702	300	5.11	4.77	4.77	3,810	18,174
1.00	1700	100	45.9	18.4	666	300	4.85	4.53	4.53	4,590	20,793
1.00	1800	100	55.0	22.0	750	300	5.45	5.09	5.09	5,500	27,995
1.00	1900	100	61.6	21.6	690	300	5.02	4.69	4.69	6,160	28,890
1.00	2000	100	65.1	26.0	704	300	5.12	4.78	4.78	6,510	31,118
1.00	2100	100	73.3	29.3	716	300	5.21	4.87	4.78	7,330	35,697
1.00	2200	100	83.2	33.3	776	300	5.64	5.27	5.27	8,320	43,846
											276,386
1.00	2300	70	94.9	38.0	852	300	6.19	5.78	5.77	6,643	38,330
.998	2340	50	84.5	33.8	888	300	6.45	6.02	6.01	4,225	25,392
.997	2400	50	84.8	33.9	846	300	61.5	5.74	5.72	4,240	24,253

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 434 ft
ΔC to LWE = 277 ft
Stream discharge measurements, 11 July 1994, mean time 1020, width 2,710 ft, area 118,000 ft^2 mean velocity 4.47 fps, maximum velocity 6.45 fps, minimum velocity 1.95 fps, discharge 527,000 ft^3/min, gage height 20.93, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 12 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
											383,973
.994	2500	55	83.2	33.3	792	300	5.76	5.38	5.35	4,576	24,482
.993	2550	90	85.1	34.0	794	300	5.77	5.39	5.35	7,659	40,976
.997	2680	115	52.2	209	654	300	4.76	4.45	4.44	6,003	26,653
.996	2780	110	64.5	25.8	456	300	3.33	3.11	3.10	7,095	21,995
											498,079
.994	2900	110	71.6	28.6	372	300	2.72	2.54	2.52	7,876	19,848
											517,927
.994	3000	122	40.5	16.8	266	300	1.95	1.82	1.81	4,941	8,943
LWE	3144	72	0.0	0.0						0	0
		2,710								118,296	526,870

Table 13
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.998	600	183	6.3	2.5	312	300	2.29	2.14	2.14	1,153	2,467
.999	800	200	10.0	4.0	404	300	2.95	2.76	2.76	2,000	5,520
.999	1000	200	14.4	5.8	498	300	3.63	3.39	3.39	2,880	9,763
1.00	1200	200	24.0	9.6	496	300	3.62	3.38	3.38	4,800	16,224
1.00	1400	150	31.5	12.6	622	300	4.53	4.23	4.23	4,725	19,987
1.00	1500	100	37.2	14.9	646	300	4.70	4.39	4.39	3,720	16,331
1.00	1600	100	38.1	15.2	660	300	4.80	4.48	4.48	3,810	17,069
1.00	1700	100	45.9	18.4	708	300	5.15	4.81	4.81	4,590	22,078
1.00	1800	100	55.0	22.0	708	300	5.15	4.81	4.81	5,500	26,455
1.00	1900	100	61.6	24.6	760	300	5.53	5.17	5.17	6,160	31,847
1.00	2000	100	65.1	26.0	756	300	5.50	5.14	5.14	6,510	33,461
1.00	2100	100	73.3	29.3	706	300	5.14	4.80	4.80	7,330	35,184
1.00	2200	100	83.2	33.3	770	300	5.60	5.23	5.23	8,320	43,514
.999	2300	70	94.9	38.0	840	300	6.11	5.71	5.70	6,643	37,865
.998	2340	50	84.5	33.8	890	300	6.47	6.04	6.03	4,225	25,477
.997	240	50	84.8	33.9	904	300	6.57	6.14	6.12	4,240	25,949
.996	2440	50	70.8	28.3	808	300	5.87	5.48	5.46	3,540	19,328

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 434 ft
ΔC to LWE = 277 ft
Stream discharge measurements, 11 July 1994, mean time 1020, width 2,710 ft, area 118,000 ft^2 mean velocity 4.53 fps, maximum velocity 6.57 fps, minimum velocity 2.29 fps, discharge 535,000 ft^3/min, gage height 20.93, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 13 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.993	2550	90	85.1	34.0	754	300	5.48	5.12	5.08	7,659	38,908
.997	2680	115	52.2	20.9	720	300	5.24	4.89	4.88	6,003	29,295
.996	2780	110	64.5	25.8	452	300	3.30	3.08	3.07	7,095	21,782
.994	2900	110	71.6	28.6	384	300	2.81	2.62	2.60	7,876	20,478
.994	3000	122	40.5	16.2	358	300	2.62	2.45	2.44	4,941	12,056
LWE	3144	72	0.0	0.0						0	0
		2,710								118,296	535,245

Table 14
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.998	600	183	6.3	2.5	306	300	2.24	2.09	2.09	1,153	2,410
.999	800	200	10.0	4.0	404	300	2.95	2.76	2.76	2,000	5,520
.999	1000	200	14.4	5.8	510	300	3.72	3.47	3.47	2,880	9,994
1.00	1300	200	24.0	9.6	482	300	3.52	3.29	3.29	11,800	15,792
1.00	1400	150	31.5	12.6	620	300	4.51	4.21	4.21	4,725	19,892
1.00	1500	100	37.2	14.9	684	300	4.98	4.65	4.65	3,720	17,298
1.00	1600	100	38.1	15.2	662	300	4.82	4.50	4.50	3,810	17,145
1.00	1700	100	45.9	18.4	664	300	4.83	4.51	4.51	4,590	20,701
1.00	1800	100	55.0	22.0	702	300	5.11	4.77	4.77	5,500	26,235
1.00	1900	100	61.6	24.6	732	300	5.32	4.97	4.97	6,160	30,615
1.00	2000	100	65.1	26.0	714	300	5.19	4.85	4.85	6,510	31,574
1.00	2100	100	73.3	29.3	682	300	4.96	4.63	4.63	7,330	33,938
1.00	2200	100	83.2	33.3	764	300	5.56	5.19	5.19	8,320	43,181
.999	2300	70	94.9	38.0	846	300	6.15	5.74	5.73	6,643	38,064
.998	2340	50	84.5	33.8	902	300	6.55	6.12	6.11	4,225	25,815
.997	2400	50	84.8	33.9	884	300	6.42	6.00	5.98	4,240	25,355
.996	2440	50	70.8	38.3	836	300	6.08	5.68	5.66	3,540	20,036

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 434 ft
ΔC to LWE = 277 ft
Stream discharge measurements, 11 July 1994, mean time 1020, width 2,710 ft, area 118,000 ft^2 mean velocity 4.42 fps, maximum velocity 6.55 fps, minimum velocity 2.24 fps, discharge 522,000 ft^3/min, gage height 20.93, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 14 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.993	2550	90	85.1	34.0	716	300	5.21	4.87	4.84	7,659	37,070
.997	2680	115	52.2	20.9	674	300	4.91	4.59	4.58	6,003	27,494
.996	2780	110	64.5	25.8	450	300	3.28	3.06	3.05	7,095	21,640
.994	2900	110	71.6	28.6	344	300	2.52	2.35	2.34	7,876	18,430
.994	3000	122	4.05	16.2	310	300	2.27	2.12	2.11	4,941	10,426
LWE	3144	72	0.0	0.0						0	0
		2,710								118,296	522,146

Table 15
Range Gage 362.34, Natchez Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	200	98	20.0	8.0	338	300	2.47	2.31	2.31	1,960	4,528
1.00	300	150	26.9	10.8	362	300	2.65	2.48	2.48	4,035	10,007
1.00	500	200	23.8	9.5	388	300	2.84	2.65	2.65	4,760	12,614
1.00	700	200	26.5	10.6	448	300	3.27	3.05	3.05	5,300	16,165
1.00	900	200	32.2	12.9	442	300	3.23	3.02	3.02	6,440	19,449
1.00	1100	200	36.5	14.6	504	300	3.68	3.44	3.44	7,300	25,112
1.00	1300	200	45.1	18.4	504	300	3.68	3.44	3.44	9,180	31,579
1.00	1500	200	54.9	22.0	520	300	3.79	3.54	3.54	10,980	38,869
1.00	1700	150	61.5	24.6	606	300	4.41	4.12	4.12	9,225	38,007
1.00	1800	100	61.9	24.8	636	300	4.63	4.32	4.32	6,190	26,741
1.00	1900	100	67.1	26.8	622	300	4.53	4.23	4.23	6,710	28,383
1.00	2000	100	71.4	28.6	634	300	4.62	4.32	4.32	7,140	30,845
1.00	2100	100	75.9	30.4	650	300	4.73	4.42	4.42	7,790	33,548
.999	2200	100	81.0	32.4	596	300	4.34	4.05	4.05	8,100	32,805
.998	2300	100	82.4	33.0	652	300	4.75	4.44	4.43	8,240	36,503
.997	2400	100	79.2	31.7	678	300	4.93	4.60	4.59	7,920	36,353
.996	2500	100	77.2	30.9	614	300	4.47	4.17	4.15	7,720	32,038

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 104 ft
ΔC to LWE = 71 ft
Stream discharge measurements, 12 July 1994, mean time 1045, width 2,870 ft, area 143,000 ft^2 mean velocity 3.60 fps, maximum velocity 4.93 fps, minimum velocity 1.81 fps, discharge 515,000 ft^3/min, gage height 27.63, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 15 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.994	2700	100	78.3	31.3	360	300	2.63	2.46	2.45	7,830	19,184
.994	2800	139	57.7	23.1	246	300	1.81	1.69	1.68	8,020	13,474
LWE	2978	89	0.0	0.0						0	0
		2,814								142,540	515,197

Table 16
Range Gage 362.34, Natchez Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	200	98	20.0	8.0	322	300	2.36	2.20	2.20	1,960	4,372
.999	300	150	26.9	10.8	420	300	3.07	2.87	2.87	4,035	11,580
1.00	500	200	23.8	9.5	404	300	2.95	2.76	2.76	4,760	13,138
1.00	700	200	26.5	10.6	422	300	3.08	2.88	2.88	5,300	15,264
1.00	900	200	32.2	12.9	450	300	3.28	3.06	3.06	6,440	19,706
1.00	1100	200	36.5	14.6	550	300	4.01	3.75	3.75	7,300	27,375
1.00	1300	200	45.9	18.4	548	300	3.99	3.73	3.73	9,180	34,241
1.00	1500	200	54.9	22.0	556	300	4.05	3.78	3.78	10,980	41,504
1.00	1700	150	61.5	24.6	634	300	4.62	4.32	4.32	9,225	39,852
1.00	1800	100	61.9	24.8	584	300	4.25	3.97	3.97	6,190	24,574
1.00	1900	100	67.1	26.8	600	300	4.37	4.08	4.08	6,710	27,377
1.00	2000	100	71.4	28.6	604	300	4.40	4.11	4.11	7,140	29,345
1.00	2100	100	75.9	30.4	646	300	4.70	4.39	4.39	7,590	33,320
.999	2200	100	81.0	32.4	682	300	4.96	4.63	4.63	8,100	37,503
.998	2300	100	82.4	33.0	684	300	4.98	4.65	4.64	8,240	38,234
.997	2400	100	79.2	31.7	706	300	5.14	4.80	4.79	7,920	37,937
.996	2500	100	77.2	30.9	669	300	4.83	4.51	4.49	7,720	34,663

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 104 ft
ΔC to LWE = 71 ft
Stream discharge measurements, 12 July 1994, mean time 1045, width 2,870 ft, area 143,000 ft^2 mean velocity 3.73 fps, maximum velocity 5.14 fps, minimum velocity 4.82 fps, discharge 534,000 ft^3/min, gage height 27.63, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 16 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.994	2700	100	78.3	31.3	398	300	2.91	2.72	2.70	7,830	21,141
.994	2800	139	57.7	23.1	248	300	1.82	1.70	1.69	8,020	13,554
LWE	2978	89	0.0	0.0						0	0
		2,874								142,540	534,245

Table 17
Range Gage 362.34, Natchez Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity: At point	Velocity: Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	200	98	20.0	8.0	322	300	2.36	2.20	2.20	1,960	4,372
.999	300	150	26.9	10.8	420	300	3.07	2.87	2.87	4,035	11,580
1.00	500	200	23.8	9.5	404	300	2.95	2.76	2.76	4,760	13,138
1.00	700	200	26.5	10.6	422	300	3.08	2.88	2.88	5,300	15,264
1.00	900	200	32.2	12.9	450	300	3.28	3.06	3.06	6,440	19,706
1.00	1100	200	36.5	14.6	550	300	4.01	3.75	3.75	7,300	27,375
1.00	1300	200	45.9	18.4	548	300	3.99	3.73	3.73	9,180	34,241
1.00	1500	200	54.9	22.0	556	300	4.05	3.78	3.78	10,980	41,504
1.00	1700	150	61.5	24.6	634	300	4.62	4.32	4.32	9,225	39,852
1.00	1800	100	61.9	24.8	584	300	4.25	3.97	3.97	6,190	24,574
1.00	1900	100	67.1	26.8	600	300	4.37	4.08	4.08	6,710	27,377
1.00	2000	100	71.4	28.6	604	300	4.40	4.11	4.11	7,140	29,345
1.00	2100	100	75.9	30.4	646	300	4.70	4.39	4.39	7,590	33,320
.999	2200	100	81.0	32.4	682	300	4.96	4.63	4.63	8,100	37,503
.998	2300	100	82.4	33.0	684	300	4.98	4.65	4.64	8,240	38,234
.997	2400	100	79.2	31.7	706	300	5.14	4.80	4.79	7,920	37,937
.996	2500	100	77.2	30.9	669	300	4.83	4.51	4.49	7,720	34,663

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 104 ft
ΔC to LWE = 71 ft
Stream discharge measurements, 12 July 1994, mean time 1045, width 2,870 ft, area 143,000 ft^2 mean velocity 3.73 fps, maximum velocity 5.14 fps, minimum velocity 4.82 fps, discharge 534,000 ft^3/min, gage height 27.63, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 17 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.994	2700	100	78.3	31.3	398	300	2.91	2.72	2.70	7,830	21,141
.994	2800	139	57.7	23.1	248	300	1.82	1.70	1.69	8,020	13,554
LWE	2978	89	0.0	0.0						0	0
		2,874								142,540	534,245

Table 18
Range Gage 402.0, Grand Gulf-Kempe Bend Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
1.00	600	135	29.1	11.6	626	300	4.56	4.26	4.26	3,929	16,738
1.00	700	100	42.5	17.0	862	300	6.27	5.86	5.86	4,250	24,905
1.00	800	100	55.0	22.0	882	300	6.41	5.99	5.99	5,500	32,945
1.00	900	150	54.2	21.7	850	300	6.18	5.77	5.77	8,130	46,910
1.00	1100	200	51.5	20.6	782	300	5.69	5.31	5.31	10,300	54,693
1.00	1300	200	49.5	19.8	786	300	5.72	5.34	5.34	9,900	52,866
1.00	1500	200	45.9	18.4	760	300	5.53	5.17	5.17	9,180	47,461
1.00	1700	200	38.1	15.2	712	300	5.18	4.84	4.84	7,620	36,881
1.00	1900	200	29.7	11.9	684	300	4.98	4.65	4.65	5,940	27,621
1.00	2100	200	25.2	10.1	642	300	4.67	4.36	4.36	5,040	21,974
1.00	2300	200	21.1	8.4	658	300	4.79	4.47	4.47	4,220	18,863
1.00	2500	200	18.0	7.2	576	300	4.20	3.92	3.92	3,600	14,112
1.00	2700	200	15.4	6.2	556	300	4.05	3.78	3.78	3,080	11,642
1.00	2900	200	11.5	4.6	550	300	4.01	3.75	3.75	2,300	8,625
1.00	3100	200	10.2	4.1	460	300	3.36	3.14	3.14	2,040	6,406
1.00	3300	200	8.9	3.6	458	300	3.34	3.12	3.12	1,780	5,554
1.00	3500	200	8.3	3.3	388	300	2.84	2.65	2.65	1,660	4,399

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 402.0 ft
ΔC to LWE = 402.0 ft
Stream discharge measurements, 13 July 1994, mean time ____, width 5,390 ft, area 114,000 ft^2 mean velocity 4.33 fps, maximum velocity 6.41 fps, minimum velocity 1.68 fps, discharge 494,000 ft^3/min, gage height _____, Δ gage _____, method coefficient 0.4, measurement interval 300 sec.

Table 18 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
1.00	3700	300	13.1	5.2	380	300	2.78	2.60	2.60	3,930	10,218
1.00	4100	400	13.8	5.5	402	300	2.94	2.75	2.75	5,520	15,180
1.00	4500	400	12.1	4.8	434	300	3.17	2.96	2.96	4,840	14,326
1.00	4900	300	9.1	3.6	370	300	2.71	2.53	2.53	2,730	6,907
1.00	5100	200	6.9	2.8	326	300	2.39	2.23	2.23	1,380	3,077
1.00	5300	200	11.8	4.7	248	300	1.82	1.70	1.70	2,360	4,012
1.00	5500	200	12.3	4.9	242	300	1.78	1.66	1.66	2,460	4,084
1.00	5700	159	15.0	6.0	228	300	1.68	1.57	1.57	2,385	3,744
RWE	5818	59	0.0	0.0						0	0
		5,388								114,074	494,143

Table 19
Range Gage 402.0, Grand Gulf-Kempe Bend Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
1.00	600	135	29.1	11.6	612	300	4.46	4.17	4.17	3,929	16,384
1.00	700	100	42.5	17.0	898	300	6.53	6.10	6.10	4,250	25,925
1.00	800	100	55.0	22.0	894	300	6.50	6.07	6.07	5,500	33,385
1.00	900	150	54.2	21.7	844	300	6.13	5.73	5.73	8,130	46,585
1.00	1100	200	51.5	20.6	836	300	6.08	5.68	5.68	10,300	58,504
1.00	1300	200	49.5	19.8	780	300	5.67	5.30	5.30	9,900	52,470
1.00	1500	200	45.9	18.4	748	300	5.44	5.08	5.08	9,180	46,634
1.00	1700	200	38.1	15.2	716	300	5.21	4.87	4.87	7,620	37,109
1.00	1900	200	29.7	11.9	696	300	5.06	4.73	4.73	5,940	28,096
1.00	2100	200	25.2	10.1	760	300	5.53	5.17	5.17	5,040	26,057
1.00	2300	200	21.1	8.4	622	300	4.53	4.23	4.23	4,220	17,851
1.00	2500	200	18.0	7.2	592	300	4.31	4.03	4.03	3,600	14,508
1.00	2700	200	15.4	6.2	550	300	4.01	3.75	3.75	3,080	11,550
1.00	2900	200	11.5	4.6	558	300	4.07	3.80	3.80	2,300	8,740
1.00	3100	200	10.2	4.1	544	300	3.96	3.70	3.70	2,040	7,548
1.00	3300	200	8.9	3.6	470	300	3.43	3.20	3.20	1,780	5,696
1.00	3500	200	8.3	3.3	458	300	3.34	3.12	3.12	1,660	5,179

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 402.0 ft
ΔC to LWE = 402.0 ft
Stream discharge measurements, 13 July 1994, mean time ____, width 5,390 ft, area 114,000 ft^2 mean velocity 4.43 fps, maximum velocity 6.53 fps, minimum velocity 1.75 fps, discharge 505,000 ft^3/min, gage height ____, Δ gage ____, method coefficient 0.4, measurement interval 300 sec.

Table 19 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
1.00	3700	300	13.1	5.2	406	300	2.97	2.77	2.77	3,930	10,886
1.00	4100	400	13.8	5.5	402	300	2.94	2.75	1.75	5,520	15,180
1.00	4500	300	12.1	4.8	434	300	3.17	2.96	2.96	3,630	10,745
1.00	4700	200	10.3	4.1	410	300	3.00	2.80	2.80	2,060	5,768
1.00	4900	200	9.1	3.6	342	300	2.50	2.34	2.34	1,820	4,259
1.00	5100	200	6.9	2.8	326	300	2.39	2.23	2.23	1,380	3,077
1.00	5300	200	11.8	4.7	272	300	2.00	1.87	1.87	2,360	4,413
1.00	5500	200	12.3	4.9	252	300	1.85	1.73	1.73	2,460	4,256
1.00	5700	159	15.0	6.0	238	300	1.75	1.63	1.63	2,385	3,888
RWE	5818	59	0.0	0.0						0	0
		5,388								114,014	504,693

Table 20
Range Gage 402.0, Grand Gulf-Kempe Bend Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
1.00	600	135	29.1	11.6	616	300	4.49	4.19	4.19	3,929	16,463
1.00	700	100	42.5	17.0	936	300	6.80	6.35	6.35	4,250	26,988
1.009	800	100	55.0	22.0	880	300	6.40	5.98	5.98	5,500	32,890
1.00	900	150	54.2	21.7	846	300	6.15	5.74	5.74	8,130	46,666
1.00	1100	200	51.5	20.6	842	300	6.12	5.72	5.72	10,300	58,916
1.00	1300	200	49.5	19.8	814	300	5.92	5.53	5.53	9,900	54,747
1.00	1500	200	45.9	18.4	762	300	5.54	5.17	5.17	9,180	47,461
1.00	1700	200	38.1	15.2	732	300	5.32	4.97	4.97	7,620	37,871
1.00	1900	200	29.7	11.9	634	300	4.62	4.32	4.32	5,940	25,041
1.00	2100	200	25.2	10.1	702	300	5.11	4.77	4.77	5,040	24,041
1.00	2300	200	21.1	8.4	606	300	4.41	4.12	4.12	4,220	17,386
1.00	2500	200	18.0	7.2	572	300	4.17	3.89	3.89	3,600	14,004
1.00	2700	200	15.4	6.2	512	300	3.73	3.48	3.48	3,080	10,718
	2900	200	11.5	4.6	482	300	3.52	3.29	3.29	2,300	7,567
1.00	3100	200	10.2	4.1	514	300	3.75	3.50	3.50	2,040	7,140
1.00	3300	200	8.9	3.6	446	300	3.26	3.04	3.04	1,780	5,411
1.00	3500	200	8.3	3.3	470	300	3.43	3.20	3.20	1,660	5,312

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 402.0 ft
ΔC to LWE = 402.0 ft
Stream discharge measurements, 13 July 1994, mean time ____, width 5,390 ft, area 114,000 ft^2 mean velocity 4.39 fps, maximum velocity 6.80 fps, minimum velocity 1.76 fps, discharge 501,000 ft^3/min, gage height _____, Δ gage ____, method coefficient 0.4, measurement interval 300 sec.

Table 20 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
1.00	3700	300	13.1	5.2	354	300	2.59	2.42	2.42	3,930	9,511
1.00	4100	400	13.8	5.5	414	300	3.02	2.82	2.82	5,520	15,566
1.00	4500	300	12.1	4.8	434	300	3.17	2.96	2.96	3,630	10,745
1.00	4700	200	10.3	4.1	416	300	3.04	2.84	2.84	2,060	5,850
1.00	4900	200	9.1	3.6	346	300	2.53	2.36	2.36	1,820	4,295
1.00	5100	200	6.9	2.8	316	300	2.32	2.17	2.17	1,380	2,995
1.00	5300	200	11.8	4.7	272	300	2.00	1.87	1.87	2,360	4,413
1.00	5500	200	12.3	4.9	260	300	1.91	1.78	1.78	2,460	4,379
1.00	5700	159	15.0	6.0	240	300	1.76	1.64	1.64	2,385	3,911
LWE	5818	59	0.0	0.0						0	0
		5,388								114,014	500,907

Table 21
Range Gage 565.9, Chicot Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.800	2100	68	11.4	4.6	50	300	0.38	0.35	0.28	775	217
.997	2200	100	36.0	14.4	86	300	0.64	0.60	0.60	3,600	2,160
.998	2300	100	49.4	19.8	170	300	1.26	1.18	1.18	4,940	5,829
.998	2400	100	52.0	20.8	282	300	2.07	1.93	1.93	5,200	10,036
.998	2500	100	53.8	21.5	348	300	2.55	2.38	2.38	5,380	13,804
.997	2600	100	54.1	21.6	460	300	3.36	3.14	3.13	5,410	16,933
.997	2700	100	54.1	21.6	540	300	3.94	3.68	3.67	5,410	19,855
.996	2800	150	54.8	21.9	596	300	4.34	4.05	4.03	8,220	33,127
.996	3000	200	50.9	20.4	608	300	4.43	4.14	4.12	10,180	41,942
.996	3200	200	52.1	20.8	604	300	4.40	4.11	4.09	10,420	42,618
.996	3400	200	53.0	21.2	584	300	4.25	3.97	3.95	10,600	41,870
.992	3600	200	57.6	23.0	554	300	4.04	3.77	3.74	11,520	43,085
.992	3800	200	56.9	22.8	470	300	3.43	3.20	3.17	11,380	36,075
.992	4000	200	50.9	20.4	478	300	3.49	3.26	3.23	10,180	32,881
.988	4200	200	45.0	18.0	485	300	3.34	3.12	3.08	9,000	27,720
.988	4400	200	38.1	15.2	434	300	3.17	2.96	2.92	7,620	22,250
.986	4600	150	30.0	12.0	374	300	2.74	2.56	2.52	4,500	11,340
.980	4700	100	27.8	11.1	272	300	2.00	1.87	1.83	2,780	5,087

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 14 July 1994, mean time 1045, width 2,910 ft, area 130,000 ft^2 mean velocity 3.15 fps, maximum velocity 4.43 fps, minimum velocity 0.38 fps, discharge 410,000 ft^3/min, gage height 13.01, Δ gage +0.06, method coefficient 0.4, measurement interval 300 sec.

Table 21 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.974	4800	100	22.0	8.8	248	300	1.82	1.70	1.66	2,220	3,652
.968	4900	89	9.0	3.6	130	300	0.96	0.90	0.87	801	697
RWE	2064	18	0.0								
LWE	4978	39	0.0								
		2,914								130,116	410,178

Table 22
Range Gage 565.9, Chicot Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.800	2100	68	11.4	4.6	58	300	0.44	0.41	0.33	775	256
.998	2200	100	36.0	14.4	126	300	0.94	0.88	0.88	3,600	3,168
.998	2300	100	49.4	19.8	180	300	1.33	1.24	1.24	4,940	6,126
.998	2400	100	52.0	20.8	320	300	2.34	2.19	2.19	5,200	11,388
.998	2500	100	53.8	21.5	404	300	2.95	2.76	2.75	5,380	14,795
.998	2600	100	54.1	21.6	444	300	3.24	3.03	3.02	5,410	16,338
.996	2700	100	54.1	21.6	528	300	3.85	3.60	3.59	5,410	19,422
.996	2800	150	54.8	21.9	536	300	3.91	3.65	3.64	8,220	29,921
.996	3000	200	50.9	20.4	606	300	4.41	4.21	4.10	10,180	41,738
.996	3200	200	52.1	20.8	600	300	4.37	4.08	4.06	10,420	42,305
.996	3400	200	53.0	21.2	542	300	3.95	3.69	3.68	10,600	39,008
.996	3600	200	57.6	23.0	542	300	3.95	3.69	3.68	11,520	42,394
.992	3800	200	56.9	22.8	534	300	3.89	3.63	3.60	11,380	40,968
.992	4000	200	50.9	20.4	510	300	3.72	3.47	3.44	10,180	35,091
.990	4200	200	45.0	18.0	410	300	3.00	2.80	2.77	9,000	24,930
.988	4400	200	38.1	15.2	410	300	3.00	2.80	2.77	7,620	21,107
.988	4600	150	30.0	12.0	360	300	2.63	2.46	2.43	4,500	10,935
.984	4700	100	27.8	11.1	284	300	2.08	1.94	1.91	2,780	5,310

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 14 July 1994, mean time 1045, width 2,910 ft, area 130,000 ft^2 mean velocity 3.15 fps, maximum velocity 4.41 fps, minimum velocity 0.44 fps, discharge 409,000 ft^3/min, gage height 13.01, Δ gage +0.06, method coefficient 0.4, measurement interval 300 sec.

Table 22 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.978	4800	100	22.0	8.8	220	300	1.62	1.51	1.48	2,200	3,256
.970	4900	89	9.0	3.6	134	300	0.99	0.92	0.89	801	713
RWE	2064	18									
LWE	4978	39	0.0								
		2,914								130,116	409,097

Table 23
Range Gage 565.9, Chicot Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.764	2100	68	11.4	4.6	52	300	-0.40	-0.37	-0.28	775	-217
.998	2200	100	36.0	14.4	110	300	0.82	0.77	0.77	3,600	2,772
.998	2300	100	49.4	19.8	228	300	1.68	1.57	1.57	4,940	7,756
.997	2400	100	52.0	20.8	256	300	1.88	1.76	1.75	5,200	9,100
.997	2500	100	53.8	21.5	416	300	3.04	2.84	2.83	5,380	15,225
.997	2600	150	54.1	21.6	470	300	3.43	3.20	3.19	8,115	25,887
.995	2800	200	54.8	21.9	600	300	4.37	4.08	4.06	10,960	44,498
.994	3000	200	50.9	20.4	620	300	4.51	4.21	4.18	10,180	42,552
.994	3200	200	52.1	20.8	620	300	4.51	4.21	4.18	10,420	43,556
.988	3400	200	53.0	21.2	590	300	4.30	4.02	3.97	10,600	42,082
.988	3600	200	57.6	23.0	554	300	4.04	3.77	3.72	11,520	42,854
.988	3800	200	56.9	22.8	498	300	3.63	3.39	3.35	11,380	38,123
.988	4000	200	50.9	20.4	454	300	3.31	3.09	3.05	10,180	31,049
.986	4200	200	45.0	18.0	448	300	3.27	3.05	3.01	9,000	27,090
.986	4400	150	38.1	15.2	434	300	3.17	2.96	2.92	5,715	16,688
.984	4500	100	32.6	13.0	426	300	3.11	2.90	2.85	3,260	9,291
.982	4600	150	30.0	12.0	356	300	2.61	2.44	2.40	3,000	7,200
.982	4700	100	27.8	11.1	306	300	2.24	2.09	2.05	2,780	5,699

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 14 July 1994, mean time ____, width 2,910 ft, area 130,000 ft^2 mean velocity 3.19 fps, maximum velocity 4.51 fps, minimum velocity 0.40 fps, discharge 415,000 ft^3/min, gage height 13.01, Δ gage +0.06, method coefficient 0.4, measurement interval 300 sec.

Table 23 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.976	4800	100	22.0	8.8	214	300	1.58	1.48	1.44	2,200	3,168
.970	4900	89	9.0	3.6	124	300	0.92	0.86	0.83	801	665
RWE	2064	18									
LWE	4978	39	0.0								
		2,914								130,006	415,038

Table 24
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.998	700	222	6.5	2.6	292	300	2.14	2.00	2.00	1,443	2,886
.999	900	200	11.3	4.5	394	300	2.88	2.69	2.69	2,260	6,079
.999	1100	150	15.6	6.2	432	300	3.15	2.94	2.94	2,340	6,880
1.00	1200	100	21.2	8.5	452	300	3.30	3.08	3.08	2,120	6,530
1.00	1300	100	26.9	10.8	520	300	3.79	3.54	3.54	2,690	9,523
1.00	1400	100	32.2	12.9	556	300	4.05	3.78	3.78	3,220	12,172
1.00	1500	100	34.7	13.9	588	300	4.28	4.00	4.00	3,470	13,880
1.00	1600	100	40.5	16.2	590	300	4.30	4.02	4.02	4,050	16,281
1.00	1700	100	44.0	17.6	670	300	4.88	4.56	4.56	4,440	20,064
1.00	1800	100	49.0	19.6	744	300	5.41	5.05	5.05	4,900	24,745
1.00	1900	100	57.8	23.1	730	300	5.31	4.96	4.96	5,780	28,669
1.00	2000	100	66.3	26.5	708	300	5.15	4.81	4.81	6,630	31,890
1.00	2100	100	71.5	28.6	672	300	4.89	4.57	4.57	7,150	32,676
1.00	2200	100	82.0	32.8	718	300	5.22	4.88	4.88	8,200	40,016
.999	2300	70	89.0	35.6	790	300	5.74	5.36	5.75	6,230	33,331
.998	2340	50	74.9	30.00	842	300	6.12	5.72	5.71	3,745	32,384
.997	2400	50	82.8	33.1	726	300	5.28	4.93	4.92	4,140	20,369

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 456 ft
ΔC to LWE = 287 ft
Stream discharge measurements, 15 July 1994, mean time 1045, width 2,680 ft, area 114,000 ft^2 mean velocity 4.13 fps, maximum velocity 6.12 fps, minimum velocity 1.55 fps, discharge 471,000 ft^3/min, gage height 18.84, Δ gage ____, method coefficient 0.4, measurement interval 300 sec.

Table 24 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.995	2500	55	81.0	32.4	798	300	5.80	5.42	5.39	4,455	24,012
.994	2550	90	83.4	33.4	702	300	5.11	4.77	4.74	7,506	35,578
.994	2550	90	83.4	33.4	702	300	5.11	4.77	4.74	7,506	35,578
.997	2680	115	48.5	19.4	594	300	4.33	4.04	4.03	5,578	22,479
.996	2780	110	72.2	28.9	404	300	2.95	2.76	2:75	7,942	21,841
.994	2900	110	69.3	27.7	324	300	2.37	2.21	2.20	7,623	16,771
.994	3000	117	38.2	15.3	210	300	1.55	1.45	1.44	4,469	6,435
LWE	3134	67	0.0	0.0						0	0
		2,678								113,836	471,127

Table 25
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.998	700	222	6.5	2.6	320	300	2.34	2.19	2.19	1,443	3,160
.999	900	150	11.3	4.5	418	300	3.05	2.85	2.85	2,260	6,441
.999	1100	100	15.6	6.2	466	300	3.40	3.18	3.18	2,340	7,442
1.00	1200	100	21.2	8.5	448	300	3.27	3.05	3.05	2,120	6,466
1.00	1300	100	26.9	10.8	500	300	3.65	3.41	3.41	2,690	9,173
1.00	1400	100	32.2	12.8	586	300	4.27	3.99	3.99	3,220	12,848
1.00	1500	100	34.7	13.9	606	300	4.41	4.12	4.12	3,470	14,296
1.00	1600	100	40.5	16.2	608	300	4.43	4.14	4.14	4,050	16,767
1.00	1700	100	44.0	17.6	652	300	4.75	4.44	4.44	4,440	19,536
1.00	1800	100	49.0	19.6	750	300	5.45	5.09	5.09	4,900	24,941
1.00	1900	100	57.8	23.1	696	300	5.06	4.73	4.73	5,780	27,339
1.00	2000	100	66.3	26.5	716	300	5.21	4.87	4.87	6,630	32,288
1.00	2100	100	71.5	28.6	694	300	5.05	4.72	4.72	7,150	33,748
1.00	2200	100	82.0	32.8	736	300	5.35	5.00	5.00	8,200	41,000
.999	2300	70	89.0	35.6	794	300	5.77	5.39	5.38	6,230	33,517
.998	2340	50	74.9	30.0	856	300	6.22	5.81	5.80	3,745	21,721
.997	2400	50	82.8	33.1	752	300	5.47	5.11	5.09	4,140	21,073

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 456 ft
ΔC to LWE = 287 ft
Stream discharge measurements, 15 July 1994, mean time 1045, width 2,680 ft, area 114,000 ft^2 mean velocity 4.11 fps, maximum velocity 6.22 fps, minimum velocity 1.63 fps, discharge 469,000 ft^3/min, gage height 18.84, Δ gage ____, method coefficient 0.4, measurement interval 300 sec.

Table 25 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.995	2500	55	81.0	32.4	770	300	5.60	5.23	5.20	4,455	23,166
.994	2550	90	83.4	33.4	624	300	4.54	4.24	4.21	7,506	31,600
.997	2680	115	48.5	19.4	622	300	4.53	4.23	4.22	5,578	23,539
.996	2780	110	72.2	28.9	372	300	2.72	2.54	2.53	7,942	20,093
.995	2900	110	69.3	27.7	264	300	1.94	1.81	1.80	7,623	13,721
.994	3000	117	38.2	15.3	222	300	1.63	1.52	1.51	4,469	6,748
LWE	3134	67	0.0	0.0						0	0
		2,678								113,836	469,147

Table 26
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.998	700	222	6.5	2.6	294	300	2.16	2.02	2.02	1,443	2,915
.999	900	200	11.3	4.5	404	300	2.95	2.76	2.76	2,260	6,238
1.00	1100	150	15.6	6.2	490	300	3.57	3.33	3.33	2,340	7,792
1.00	1200	100	21.2	8.5	488	300	3.56	3.33	3.33	2,120	7,060
1.00	1300	100	26.9	10.8	514	300	3.75	3.50	3.50	2,690	9,415
1.00	1400	100	32.2	12.9	566	300	4.12	3.85	3.85	3,220	12,397
1.00	1500	100	34.7	13.9	592	300	4.31	4.03	4.03	3,470	13,984
1.00	1600	100	40.5	16.2	574	300	4.18	3.90	3.90	4,050	15,795
1.00	1700	100	44.0	17.6	642	300	4.67	4.36	4.36	4,440	19,184
1.00	1800	100	49.0	19.6	712	300	5.18	4.84	4.84	4,900	23,716
1.00	1900	100	57.8	23.1	738	300	5.37	5.02	5.02	5,780	29,016
1.00	2000	100	66.3	26.5	718	300	5.22	4.88	4.88	6,630	32,354
1.00	2100	100	71.5	28.6	682	300	4.96	4.63	4.63	7,150	33,105
1.00	2200	100	82.0	32.8	706	300	5.14	4.80	4.80	8,200	39,360
.999	2300	70	89.0	35.6	806	300	5.86	5.47	5.46	6,230	34,016
.998	2340	50	74.9	30.0	850	300	6.18	5.77	5.76	3,745	21,571
.997	2400	50	82.8	33.1	822	300	5.98	5.59	5.57	4,140	23,060

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 456 ft
ΔC to LWE = 287 ft
Stream discharge measurements, 15 July 1994, mean time 1045, width 2,680 ft, area 114,000 ft^2 mean velocity 4.15 fps, maximum velocity 6.18 fps, minimum velocity 2.05 fps, discharge 473,000 ft^3/min, gage height 18.84, Δ gage ____, method coefficient 0.4, measurement interval 300 sec.

Table 26 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.995	2500	55	81.0	32.4	702	300	5.11	4.77	4.75	4,455	21,161
.994	2550	90	83.4	33.4	696	300	5.06	4.73	4.70	7,506	35,278
.997	2680	115	48.5	19.4	636	300	4.63	4.32	4.31	5,578	24,041
.996	2780	110	72.2	28.9	396	300	2.90	2.71	2.70	7,942	21,443
.994	2900	110	69.3	27.7	306	300	2.24	2.09	2.08	7,623	15,856
.994	3000	117	38.2	15.3	280	300	2.05	1.91	1.90	4,469	8,491
LWE	3134	67	0.0	0.0						0	0
		2,678								113,836	473,150

Table 27
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	1000	180	6.3	2.5	118	300	0.88	0.82	0.82	1,134	930
1.00	1200	200	11.6	4.6	250	300	1.84	1.72	1.72	2,320	3,990
1.00	1400	150	21.4	8.6	378	300	2.76	2.58	2.58	3,210	8,282
1.00	1500	100	23.4	9.4	430	300	3.14	2.93	2.93	2,340	6,856
1.00	1600	100	27.6	11.0	442	300	3.23	3.02	3.02	2,760	8,335
1.00	1700	100	35.0	14.0	474	300	3.46	3.23	3.23	3,500	11,305
1.00	1800	100	45.2	18.1	482	300	3.52	3.29	3.29	4,520	14,871
1.00	1900	100	57.5	23.0	526	300	3.83	3.58	3.58	5,750	20,585
1.00	2000	100	62.3	24.9	482	300	3.52	3.29	3.29	6,230	20,497
1.00	2100	100	66.2	26.5	536	300	3.91	3.65	3.65	6,620	24,163
1.00	2200	100	70.8	28.3	632	300	4.60	4.30	4.30	7,080	30,444
.999	2300	70	77.2	30.9	580	300	4.23	3.95	3.95	5,404	21,346
.998	2340	50	65.0	26.0	642	300	4.67	4.36	4.35	3,250	14,138
.997	2400	50	72.5	29.0	622	300	4.53	4.23	4.22	3,625	15,298
.996	2440	50	61.4	24.6	592	300	4.31	4.03	4.01	3,070	12,311
.995	2500	55	70.2	28.1	538	300	3.92	3.66	3.64	3,861	14,054
.999	2550	90	70.9	28.4	510	300	3.72	3.47	3.45	6,381	22,014

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 840 ft
ΔC to LWE = 347 ft
Stream discharge measurements, 19 Sept 1994, mean time 1150, width 2,230 ft, area 238,000 ft^2 mean velocity 3.13 fps, maximum velocity 4.67 fps, minimum velocity 0.88 fps, discharge 283,000 ft^3/min, gage height 8.94, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 27 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.997	2680	115	38.9	15.6	444	300	3.24	3.03	3.02	4,474	13,511
.996	2780	110	64.0	25.6	230	300	1.69	1.58	1.57	7,040	11,053
.994	2900	147	54.0	21.6	170	300	1.26	1.18	1.17	7,938	9,287
LWE	3074	87	0.0	0.0						0	0
		2,234								90,507	283,270

Table 28
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.999	1000	180	6.3	2.5	134	300	0.99	0.92	0.92	1,134	1,043
1.00	1200	200	11.6	4.6	248	300	1.82	1.70	1.70	2,320	3,944
1.00	1400	150	21.4	8.6	390	300	2.85	2.66	2.66	3,210	8,539
1.00	1500	100	23.4	9.4	426	300	3.11	2.90	2.90	2,340	6,786
1.00	1600	100	27.6	11.0	440	300	3.21	3.00	3.00	2,760	8,280
1.00	1200	100	35.0	14.0	456	300	3.33	3.11	3.11	3,500	10,885
1.00	1800	100	45.2	18.1	484	300	3.53	3.30	3.30	4,520	14,916
1.00	1900	100	57.5	23.0	456	300	3.33	3.11	3.11	5,750	17,883
1.00	2000	100	62.3	24.9	484	300	3.53	3.30	3.30	6,230	20,559
1.00	2100	100	66.2	26.5	458	300	3.34	3.12	3.12	6,620	20,654
1.00	2200	100	70.8	28.3	564	300	4.11	3.87	3.84	7,080	27,187
.999	2300	70	77.2	30.9	586	300	4.27	3.99	3.99	5,404	21,562
.998	2340	50	65.0	26.0	618	300	4.50	4.20	4.19	3,250	13,618
.997	2400	50	72.5	29.0	622	300	4.53	4.23	4.22	3,625	15,298
.996	2440	50	61.4	24.6	570	300	4.15	3.88	3.86	3,070	11,850
.995	2500	55	70.2	28.1	546	300	3.98	3.72	3.70	3,861	14,286
.994	2550	90	70.9	28.4	556	300	4.05	3.78	3.76	6,381	23,993

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 840 ft
ΔC to LWE = 347 ft
Stream discharge measurements, 19 Sept 1994, mean time 1115, width 2,234 ft, area 90,500 ft^2 mean velocity 3.12 fps, maximum velocity 4.53 fps, minimum velocity 0.99 fps, discharge 282,000 ft^3/min, gage height 8.94, Δ gage -0.08, method coefficient 0.4, measurement interval 300 sec.

Table 28 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.997	2680	115	38.9	15.6	520	300	3.79	3.54	3.53	4,474	15,793
.996	2780	110	64.0	25.6	286	300	2.10	1.96	1.95	7,040	13,728
.994	2900	147	54.0	21.6	200	300	1.47	1.37	1.36	7,938	10,796
LWE	3074	87	0.0	0.0						0	0
		2,234								90,507	281,600

Table 29
Range Gage 362.34, Natchez Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity: At point	Velocity: Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	300	176	12.3	4.9	118	300	0.88	0.82	0.82	2,165	1,775
1.00	500	200	9.1	3.6	162	300	1.20	1.12	1.12	1,820	2,038
1.00	700	200	15.2	6.1	198	300	1.46	1.36	1.36	3,040	4,134
1.00	900	200	22.4	9.0	240	300	1.76	1.64	1.64	4,480	7,347
1.00	1100	200	26.2	10.5	288	300	2.11	1.97	1.97	5,240	10,323
1.00	1300	200	30.4	12.2	354	300	2.59	2.42	2.42	6,080	14,714
1.00	1500	150	37.8	15.1	370	300	2.71	2.53	2.53	5,670	14,345
1.00	1600	100	42.5	17.0	400	300	2.92	2.73	2.73	4,250	11,603
1.00	1700	100	46.5	18.6	426	300	3.11	2.90	2.90	4,650	13,485
1.00	1800	100	51.4	20.6	456	300	3.33	3.11	3.11	5,140	15,985
1.00	1900	100	56.4	22.6	452	300	3.30	3.08	3.08	5,640	17,371
1.00	2000	100	60.9	24.4	416	300	3.04	2.84	2.84	6,090	17,296
1.00	2100	100	66.1	26.4	456	300	3.33	3.11	3.11	6,610	20,557
1.00	2200	100	67.7	27.1	472	300	3.44	3.21	3.21	6,770	21,732
.999	2300	100	70.5	28.2	470	300	3.43	3.20	3.20	7,050	22,560
.998	2400	100	70.5	28.2	462	300	3.37	3.15	3.14	7,050	22,137
.997	2500	100	70.0	28.0	448	300	3.27	3.05	3.04	7,000	21,280

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 148 ft
ΔC to LWE = 113 ft
Stream discharge measurements, 20 Sept 1994, mean time 1010, width 2,790 ft, area 107,000 ft^2 mean velocity 2.52 fps, maximum velocity 3.44 fps, minimum velocity 0.88 fps, discharge 270,000 ft^3/min, gage height 14.49, Δ gage -0.04, method coefficient 0.4, measurement interval 300 sec.

Table 29 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.996	2600	100	64.2	25.7	380	300	2.78	2.60	2.59	6,420	16,628
.995	2700	100	64.2	25.7	214	300	1.58	1.48	1.47	6,420	9,437
.994	2800	118	43.7	17.5	148	300	1.10	1.03	1.02	5,157	5,260
LWE	2936	68	0.0	0.0						0	0
		2,788								106,742	270,007

Table 30
Range Gage 362.34, Natchez Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	300	176	12.3	4.9	180	300	1.33	1.24	1.24	2,165	2,685
1.00	500	200	9.1	3.6	194	300	1.43	1.34	1.34	1,820	2,439
1.00	700	200	15.2	6.1	214	300	1.58	1.48	1.48	3,040	4,499
1.00	900	200	22.4	9.0	236	300	1.73	1.62	1.62	4,480	7,258
1.00	1100	200	26.2	10.5	302	300	2.21	2.06	2.06	5,240	10,794
1.00	1300	200	30.4	12.2	372	300	2.72	2.54	2.54	6,080	15,443
1.00	1500	150	37.8	15.1	416	300	3.04	2.84	2.84	5,670	16,103
1.00	1600	100	42.5	17.0	402	300	2.94	2.75	2.75	4,250	11,688
1.00	1700	100	46.5	18.6	392	300	2.87	2.68	2.68	4,650	12,462
1.00	1800	100	51.4	20.6	444	300	3.24	3.03	3.03	5,140	15,574
1.00	1900	100	56.4	22.6	396	300	2.90	2.71	2.71	5,640	15,284
1.00	2000	100	60.9	24.4	410	300	3.00	2.80	2.80	6,090	17,052
1.00	2100	100	66.1	26.4	414	300	3.02	2.82	2.82	6,610	18,640
1.00	2200	100	67.7	27.1	488	300	3.56	3.33	3.33	6,770	22,544
.999	2300	100	70.5	28.2	504	300	3.68	3.44	3.44	7,050	24,252
.998	2400	100	70.0	28.2	458	300	3.34	3.12	3.11	7,050	21,926
.997	2500	100	70.0	28.0	420	300	3.07	2.87	2.86	7,000	20,020

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 148 ft
ΔC to LWE = 113 ft
Stream discharge measurements, 20 Sept 1994, mean time 1010, width 2,790 ft, area 107,000 ft^2 mean velocity 2.50 fps, maximum velocity 3.68 fps, minimum velocity 0.83 fps, discharge 268,000 ft^3/min, gage height 14.49, Δ gage -0.04, method coefficient 0.4, measurement interval 300 sec.

Table 30 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.996	2600	100	64.2	25.7	374	300	2.74	2.56	2.55	6,420	16,371
.995	2700	100	64.2	25.7	200	300	1.47	1.37	1.36	6,420	8,731
.994	2800	118	43.7	17.5	112	300	0.83	0.78	0.78	5,157	4,022
LWE	2936	68	0.0	0.0						0	0
		2,788								106,742	267,787

Table 31
Range Gage 402.0, Grand Gulf-Kempe Bend Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.99	600	110	17.9	7.2	500	300	3.65	3.41	3.38	1,969	6,655
1.00	700	100	38.6	15.4	734	300	5.34	4.99	4.99	3,860	19,261
1.00	800	100	49.0	19.6	820	300	5.96	5.57	5.57	4,900	27,293
1.00	900	100	42.2	16.9	852	300	6.19	5.78	5.78	4,220	24,392
1.00	1000	100	46.1	18.4	856	300	6.22	5.81	5.81	4,610	26,784
1.00	1100	100	43.0	17.2	852	300	6.19	5.78	5.78	4,300	24,854
1.00	1200	100	41.2	16.5	776	300	5.64	5.27	5.27	4,120	21,712
1.00	1300	100	41.7	16.7	746	300	5.43	5.07	5.07	4,170	21,142
1.00	1400	100	35.6	14.2	756	300	5.50	5.14	5.14	3,560	18,298
1.00	1500	100	32.4	13.0	704	300	5.12	4.78	4.78	3,240	15,487
1.00	1600	100	29.9	12.0	690	300	5.02	4.69	4.69	2,990	14,023
1.00	1700	100	28.8	11.5	592	300	4.31	4.03	4.03	2,880	11,606
1.00	1800	100	18.3	7.3	616	300	4.49	4.19	4.19	1,830	7,668
1.00	1900	100	15.4	6.2	564	300	4.11	3.84	3.84	1,540	5,914
.99	2000	100	14.8	5.9	498	300	3.63	3.39	3.36	1,480	4,973
.99	2100	100	13.5	5.4	442	300	3.23	3.02	2.99	1,350	4,037
.99	2200	100	12.3	4.9	416	300	3.04	2.84	2.81	1,230	3,456
.99	2300	100	7.1	2.8	412	300	3.01	2.81	2.78	710	1,974

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 21 Sept 1994, width 2,220 ft, area 54,300 ft^2 mean velocity 4.83 fps, maximum velocity 6.22 fps, minimum velocity 2.07 fps, discharge 262,000 ft^3/min, method coefficient 0.4, measurement interval 300 sec.

Table 31 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.99	2400	100	5.9	2.4	336	300	2.46	2.30	2.28	590	1,345
.99	2500	150	5.0	2.0	282	300	2.07	1.93	1.91	750	1,433
RWE	2700	100	0.0	0.0						0	0
		2,220								54,299	262,307

Table 32
Range Gage 402.0, Grand Gulf-Kempe Bend Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.99	600	110	17.9	7.2	526	300	3.83	3.58	3.54	1,969	6,970
1.00	700	100	38.6	15.4	802	300	5.83	5.45	5.45	3,860	21,037
1.00	800	100	49.0	19.6	834	300	6.06	5.66	5.66	4,900	27,734
1.00	900	100	42.2	16.9	856	300	6.22	5.81	5.81	4,220	24,518
1.00	1000	100	46.1	18.4	834	300	6.06	5.66	5.66	4,610	26,093
1.00	1100	100	43.0	17.2	860	300	6.25	5.84	5.84	4,300	25,112
1.00	1200	100	41.2	16.5	790	300	5.74	5.36	5.36	4,120	22,083
1.00	1300	100	41.7	16.7	738	300	5.37	5.02	5.02	4,170	20,933
1.00	1400	100	35.6	14.2	748	300	5.44	5.08	5.08	3,560	18,085
1.00	1500	100	32.4	13.0	688	300	5.01	4.68	4.68	3,240	15,163
1.00	1600	100	29.9	12.0	674	300	4.91	4.59	4.59	2,990	13,724
1.00	1700	100	28.8	11.5	594	300	4.33	4.04	4.04	2,880	11,635
.99	1800	100	18.3	7.3	586	300	4.27	3.99	3.95	1,830	7,229
.99	1900	100	15.4	6.2	592	300	4.31	4.03	3.99	1,540	6,145
.99	2000	100	14.8	5.9	526	300	3.83	3.58	3.54	1,480	5,239
.99	2100	100	13.5	5.4	420	300	3.07	2.87	2.84	1,350	3,834
.99	2200	100	12.3	4.9	426	300	3.11	2.90	2.87	1,230	3,530

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 402.0 ft
ΔC to LWE = 2,700 ft
Stream discharge measurements, 21 Sept 1994, mean time ____, width 2,220 ft, area 54,300 ft^2, mean velocity 4.86 fps, maximum velocity 6.25 fps, minimum velocity 2.34 fps, discharge 264,000 ft^3/min, gage height _____, Δ gage _____, method coefficient 0.4, measurement interval 300 sec.

Table 32 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.99	2300	100	7.1	2.8	460	300	3.36	3.14	3.11	710	2,208
.99	2400	100	5.9	2.4	376	300	2.75	2.57	2.54	590	1,499
.99	2500	150	5.0	2.0	320	300	2.39	2.19	2.17	750	1,628
RWE	2700	100	0.0	0.0						0	0
		2,220								54,299	264,399

Table 33
Range Gage 565.9, Chicot Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity: At point	Velocity: Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.880	2200	110	26.8	10.7	50	300	0.38	0.35	0.31	2,948	914
.998	2300	100	41.0	16.4	140	300	1.04	0.97	0.97	4,100	3,977
.998	2400	100	44.0	17.6	172	300	1.27	1.19	1.19	4,440	5,236
.998	2500	100	45.5	18.2	242	300	1.78	1.66	1.66	4,550	7,553
.998	2600	100	46.0	18.4	294	300	2.16	2.02	2.02	4,600	9,292
.996	2700	100	45.4	18.2	354	300	2.59	2.42	2.41	4,540	10,941
.994	2800	150	46.0	18.3	386	300	2.82	2.63	2.61	6,900	18,009
.994	3000	200	48.5	19.4	392	300	2.87	2.68	2.66	9,700	25,802
.992	3200	200	45.5	18.2	440	300	3.21	3.00	2.98	9,100	27,118
.992	3400	200	50.6	20.2	390	300	2.85	2.66	2.64	10,120	26,717
.990	3600	200	48.4	19.4	410	300	3.00	2.80	2.77	9,680	26,814
.990	3800	200	50.0	20.0	354	300	2.59	2.42	2.40	10,000	24,000
.988	4000	200	43.1	17.2	340	300	2.49	2.33	2.30	8,620	19,826
.988	4200	150	36.8	14.7	360	300	2.63	2.46	2.43	5,520	13,414
.986	4300	100	35.1	14.0	348	300	2.55	2.38	2.35	3,510	8,248
.986	4400	100	31.0	12.4	328	300	2.40	2.24	2.21	3,100	6,851
.986	4500	100	25.9	10.4	320	300	2.34	2.19	2.16	2,590	5,594
.984	4600	100	20.0	8.0	284	300	2.08	1.94	1.91	2,000	3,820

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 29 Sept 1994, mean time 1030, width 2,830 ft, area 109,000 ft^2 mean velocity 2.28 fps, maximum velocity 3.21 fps, minimum velocity 0.38 fps, discharge 248,000 ft^3/min, gage height 2.98, Δ gage -0.04, method coefficient 0.4, measurement interval 300 sec.

Table 33 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.980	4700	100	17.6	7.0	248	300	1.82	1.70	1.67	1,760	2,939
.974	4800	103	11.8	4.7	168	300	1.24	1.16	1.13	1,215	1,373
LWE	4906	53	0.0	0.0							
		2,826								108,953	248,438

Table 34
Range Gage 565.9, Chicot Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.860	2200	110	26.8	10.7	74	300	0.56	0.52	0.45	2,948	1,327
.998	2300	100	41.0	16.4	124	300	0.92	0.86	0.86	4,100	3,526
.998	2400	100	44.0	17.6	172	300	1.27	1.19	1.19	4,400	5,236
.998	2500	100	45.5	18.2	212	300	1.56	1.46	1.46	4,550	6,643
.998	2600	100	46.0	18.4	284	300	2.08	1.94	1.94	4,600	8,924
.998	2700	100	45.4	18.2	328	300	2.40	2.24	2.24	4,540	10,170
.994	2800	150	46.0	18.4	374	300	2.74	2.56	2.54	6,900	17,526
.994	3000	200	48.5	19.4	388	300	2.84	2.65	2.63	9,700	25,511
.994	3200	200	45.5	18.2	454	300	3.31	3.09	3.07	9,100	27,937
.992	3400	200	50.6	20.2	340	300	2.49	2.33	2.31	10,120	23,377
.992	3600	200	48.4	19.4	404	300	2.95	2.76	2.74	9,680	26,523
.992	3800	200	50.0	20.0	384	300	2.81	2.62	2.60	10,000	26,000
.988	4000	200	43.1	17.2	344	300	2.52	2.35	2.32	8,620	19,998
.986	4200	150	36.8	14.7	364	300	2.66	2.48	2.45	5,520	13,524
.986	4300	100	35.1	14.0	340	300	2.49	2.33	2.30	3,510	8,073
.986	4400	100	31.0	12.4	312	300	2.29	2.14	2.11	3,100	6,541
.985	4500	100	25.9	10.4	312	300	2.29	2.14	2.11	2,590	5,465
.992	4600	100	20.0	8.0	274	300	2.01	1.88	1.85	2,000	3,700

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 29 Sept 1994, mean time 1030, width 2,830 ft, area 109,000 ft^2 mean velocity 2.24 fps, maximum velocity 3.31 fps, minimum velocity 0.56 fps, discharge 244,000 ft^3/min, gage height 2.98, Δ gage -0.04, method coefficient 0.4, measurement interval 300 sec.

Table 34 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.978	4700	100	17.6	7.0	220	300	1.62	1.51	1.48	1,760	2,605
.976	4800	103	11.8	4.7	156	300	1.15	1.07	1.04	1,215	1,264
LWE	4906	53	0.0								
		2,826								108,953	243,870

Table 35
Range Gage 565.9, Chicot Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.860	2200	110	26.8	10.7	70	300	0.53	0.50	0.43	2,948	1,268
.998	2300	100	41.0	16.4	120	300	0.89	0.83	0.83	4,100	3,403
.998	2400	100	44.0	17.6	178	300	1.31	1.22	1.22	4,400	5,368
.998	2500	100	45.5	18.2	244	300	1.79	1.67	1.67	4,550	7,598
.997	2600	100	46.0	18.4	300	300	2.20	2.05	2.04	4,600	9,384
.997	2700	100	45.4	18.2	338	300	2.47	2.31	2.30	4,540	10,442
.996	2800	150	46.0	18.4	348	300	2.55	2.38	2.37	6,900	16,353
.996	3000	200	48.5	19.4	386	300	2.82	2.63	2.62	9,700	25,414
.994	3200	200	45.5	18.2	428	300	3.13	2.92	2.90	9,100	26,390
.994	3400	200	50.6	20.2	376	300	2.75	2.57	2.55	10,120	25,806
.992	3600	200	48.4	19.4	406	300	2.97	2.77	2.75	9,680	26,620
.992	3800	200	50.0	20.0	406	300	2.97	2.77	2.75	10,000	27,500
.992	4000	200	43.1	17.2	362	300	2.65	2.48	2.46	8,620	21,205
.990	4200	150	36.8	14.7	340	300	2.49	2.33	2.31	5,520	12,751
.988	4300	100	35.1	14.0	328	300	2.40	2.24	2.21	3,510	7,757
.984	4400	100	31.0	12.4	310	300	2.27	2.12	2.09	3,100	6,479
.984	4500	100	25.9	10.4	296	300	2.17	2.03	2.00	2,590	5,180
.980	4600	100	20.0	8.0	280	300	2.05	1.91	1.87	2,000	3,740

(Continued)

Notes: All distances from ΔB at right bank:
Stream discharge measurements, 29 Sept 1994, mean time 1030, width 2,830 ft, area 109,000 ft^2 mean velocity 2.27 fps, maximum velocity 3.13 fps, minimum velocity 0.53 fps, discharge 247,000 ft^3/min, gage height 2.98, Δ gage -0.04, method coefficient 0.4, measurement interval 300 sec.

Table 35 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.976	4700	100	17.6	7.0	240	300	1.76	1.64	1.60	1,760	2,816
.974	4800	103	11.8	4.7	128	300	0.95	0.89	0.87	1,215	1,057
LWE	4906	53	0.0								
		2,826								108,953	246,531

Table 36
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity At point	Velocity Mean in vertical	Adjusted by Angle Coefficient	Area	Discharge
.999	1000	165	5.8	2.3	106	300	0.79	0.74	0.74	957	708
1.00	1200	150	11.0	4.4	212	300	1.56	1.46	1.46	1,650	2,409
1.00	1300	100	15.5	6.2	290	300	2.13	1.99	1.99	1,550	3,085
1.00	1400	100	20.4	8.2	388	300	2.84	2.65	2.65	2,040	5,406
1.00	1500	100	22.9	9.2	428	300	3.13	2.92	2.92	2,290	6,687
1.00	1600	100	25.4	10.2	436	300	3.18	2.97	2.97	2,540	7,544
1.00	1700	100	34.8	13.9	464	300	3.39	3.17	3.17	3,480	11,032
1.00	1800	100	38.3	15.3	506	300	3.69	3.45	3.45	3,830	13,214
1.00	1900	100	56.6	22.6	414	300	3.02	2.82	2.82	5,660	15,961
1.00	2000	100	60.8	24.3	516	300	3.76	3.51	3.51	6,080	21,341
1.00	2100	100	65.8	26.3	480	300	3.50	3.27	3.27	6,580	21,517
1.00	2200	100	71.2	28.5	524	300	3.82	3.57	3.57	7,120	25,418
.999	2300	70	79.0	31.6	570	300	41.5	3.88	3.88	5,530	21,456
.998	2340	50	67.9	27.2	646	300	4.70	4.39	4.38	3,395	14,870
.997	2400	50	72.4	29.0	574	300	4.18	3.90	3.89	3,620	14,082
.996	2440	50	57.0	22.8	518	300	3.78	3.53	3.52	2,850	10,032
.994	2500	55	69.1	27.6	448	300	3.27	3.05	3.03	3,801	11,517

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 870 ft
ΔC to LWE = 349 ft
Stream discharge measurements, 23 Sept 1994, mean time 1020, width 2,200 ft, area 88,500 ft^2 mean velocity 2.86 fps, maximum velocity 4.70 fps, minimum velocity 0.79 fps, discharge 253,000 ft^3/min, gage height 8.33, Δ gage 0.02, method coefficient 0.4, measurement interval 300 sec.

Table 36 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.993	2550	90	69.9	27.8	432	300	3.15	2.94	2.92	6,260	18,291
.997	2680	115	38.4	15.4	276	300	2.03	1.90	1.89	4,416	8,346
.996	2780	110	63.6	25.4	246	300	1.81	1.69	1.68	6,996	11,753
.994	2900	146	53.7	21.5	164	300	1.21	1.13	1.12	7,840	8,781
LWE	3072	86	0.0	0.0						0	0
		2,202								88,489	253,450

Table 37
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.999	1000	165	5.8	2.3	96	300	0.72	0.67	0.67	957	641
1.00	1200	150	11.0	4.4	234	300	1.72	1.61	1.61	1,650	2,657
1.00	1300	100	15.5	6.2	286	300	2.10	1.96	1.96	1,550	3,038
1.00	1400	100	20.4	8.2	398	300	2.91	2.72	2.72	2,040	5,549
1.00	1500	100	22.9	9.2	416	300	3.04	2.84	2.84	2,290	6,504
1.00	1600	100	25.4	10.2	436	300	3.18	2.97	2.97	2,540	7,544
1.00	1700	100	34.8	13.9	452	300	3.30	3.08	3.08	3,480	10,718
1.00	1800	100	38.3	15.3	476	300	3.47	3.24	3.24	3,830	12,409
1.00	1900	100	56.6	22.6	450	300	3.28	3.06	3.06	5,660	17,320
1.00	2000	100	60.8	24.3	442	300	3.23	3.02	3.02	6,080	18,362
1.00	2100	100	65.8	26.3	468	300	3.42	3.19	3.19	6,580	20,990
1.00	2200	100	71.2	28.5	564	300	4.11	3.84	3.84	7,120	27,341
.999	2300	70	79.0	31.6	568	300	4.14	3.87	3.87	5,530	21,401
.998	2340	50	67.9	27.2	618	300	4.50	4.20	4.19	3,395	14,225
.997	2400	50	72.4	29.0	614	300	4.47	4.17	4.16	3,620	15,059
.996	2440	50	57.0	22.8	528	300	3.85	3.60	3.59	2,850	10,232
.995	2500	55	69.1	27.6	530	300	3.86	3.61	3.59	3,801	13,646

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 870 ft
ΔC to LWE = 349 ft
Stream discharge measurements, 23 Sept 1994, mean time 1020, width 2,200 ft, area 88,500 ft^2 mean velocity 2.88 fps, maximum velocity 4.50 fps, minimum velocity 0.72 fps, discharge 255,000 ft^3/min, gage height 8.33, Δ gage -0.02, method coefficient 0.4, measurement interval 300 sec.

Table 37 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.993	2550	90	69.9	27.8	492	300	3.59	3.35	3.33	6,264	20,859
.997	2680	115	38.4	15.4	272	300	2.00	1.87	1.86	4,416	8,214
.996	2780	110	63.6	25.4	202	300	1.49	1.39	1.38	6,996	9,654
.994	2900	146	53.7	21.5	154	300	1.14	1.06	1.05	7,840	8,232
LWE	3072	86	0.0	0.0						0	0
		2,202								88,489	254,595

Table 38
Range Gage 435.41, Vicksburg Discharges

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.999	1000	165	5.8	2.3	124	300	0.92	0.86	0.86	957	823
1.00	1200	150	11.0	4.4	220	300	1.62	1.51	1.51	1,650	2,492
1.00	1300	100	15.5	6.2	300	300	2.20	2.05	2.05	1,550	3,178
1.00	1400	100	20.4	8.2	376	300	2.75	2.57	2.57	2,040	5,243
1.00	1500	100	22.9	9.2	404	300	2.95	2.76	2.76	2,290	6,320
1.00	1600	100	25.4	10.2	452	300	3.30	3.08	3.08	2,540	7,823
1.00	1700	100	34.8	13.9	464	300	3.39	3.17	3.17	3,480	11,032
1.00	1800	100	38.3	15.3	484	300	3.55	3.30	3.30	3,830	12,639
1.00	1900	100	56.6	22.6	436	300	3.18	2.97	2.97	5,660	16,810
1.00	2000	100	60.8	24.3	484	300	3.53	3.30	3.30	6,080	20,064
1.00	2100	100	65.8	26.3	460	300	3.36	3.14	3.14	6,580	20,661
1.00	2200	100	71.2	28.5	540	300	3.94	3.68	3.68	7,120	26,202
.999	2300	70	79.0	31.6	536	300	3.91	3.65	3.65	5,530	20,185
.998	2340	50	67.9	27.2	636	300	4.63	4.32	4.31	3,395	14,632
.997	2400	50	72.4	29.0	604	300	4.40	4.11	4.10	3,620	14,842
.996	2440	50	57.0	22.8	584	300	4.25	3.97	3.95	2,850	11,258
.995	2500	55	69.1	27.6	480	300	3.50	3.27	3.25	3,801	12,353

(Continued)

Notes: All distances from ΔB at right bank:
ΔB to RWE = 870 ft
ΔC to LWE = 349 ft
Stream discharge measurements, __ Sept 1994, mean time 1020, width 2,200 ft, area 88,500 ft^2 mean velocity 2.88 fps, maximum velocity 4.63 fps, minimum velocity 0.92 fps, discharge 255,000 ft^3/min, gage height 8.33, Δ gage -0.02, method coefficient 0.4, measurement interval 300 sec.

Table 38 (Concluded)

Angle Coefficient	Dist. from initial point	Width	Depth	Observation Depth	Revolutions	Time in seconds	Velocity		Adjusted by Angle Coefficient	Area	Discharge
							At point	Mean in vertical			
.993	2550	90	69.9	27.8	450	300	3.28	3.06	3.04	6,264	19,043
.997	2680	115	38.4	15.4	320	300	2.34	2.19	2.18	4,416	9,627
.996	2780	110	63.6	25.4	244	300	1.79	1.67	1.66	6,996	11,613
.994	2900	146	53.7	21.5	152	300	1.12	1.05	1.04	7,840	8,154
LWE	3072	86	0.0	0.0						0	0
		2,202								88,489	254,994

Appendix A ADCP Discharge Calculation Methods

This appendix is a technical description of how the ADCP collects and calculates discharge data. This appendix has been published as Appendix F of "User's Manual for the RD INSTRUMENTS TRANSECT PROGRAM"[1] and is reprinted with permission of RD Instruments. The appendix includes two change releases. On a change page, a vertical bar in the left margin shows the part of text affected by the change. The last line (footer) of each page lists the effective date of the change.

[1] RD Instruments. (1992). "User's Manual for the RD INSTRUMENTS TRANSECT PROGRAM," RD Instruments, San Diego, CA, Appendix F.

APPENDIX F
FORMULAS AND CALCULATIONS

F-1. DISCHARGE CALCULATIONS

This section explains how TRANSECT calculates discharge. For the data measured by the ADCP, TRANSECT calculates discharge (middle water layer - MidQ). For the unmeasured parts of the profile (top water layer - TopQ, bottom water layer - BtmQ) TRANSECT estimates the discharge. TRANSECT accumulates these values over the entire transect (or subsection of a transect if SUBSECTIONING IS NOW = ON in the PLAYBACK menu). When <ALT-U> UNMEASURED is active, TRANSECT displays the accumulated values on the right side of the screen. The total discharge (ΣQ) is the summation of discharge in the top, middle, and bottom layers. TRANSECT also can estimate near-shore discharge and included in the total discharge in the playback menu.

Discharge is the total volume of water flowing through a cross-section of water per unit of time. TRANSECT computes this total volume discharge (ΣQ) for each ADCP ensemble and displays the estimate in the ACQUIRE and PLAYBACK modes. An ADCP measures profiles of water-current velocity relative to the vessel. The ADCP also measures the velocity of the vessel relative to the bottom and depth to the bottom for each ADCP beam. Computation of discharge depends only on these data. We do not need to know compass heading or vessel location. Furthermore, the transect can be an arbitrary curve (see Figure F-1) as long as it starts near one side of a channel and ends near the other.

The uncertainty in the discharge estimate arises from random errors, biases, and missed data (near the surface and bottom, and near the sides of a channel). TRANSECT can extrapolate near-shore discharge (near the channel sides) during playback. The algorithm for estimating discharge is adopted from Simpson and Oltmann (1990), and Gordon (1989).

There are two methods available in TRANSECT for estimating the discharge in the unmeasured parts of the profile. You can use either the CONSTANT method (i.e., "straight up and down") or a POWER law method. If you select a POWER method for either the top or bottom unmeasured part of the profile, you can select the exponent of the power law based on flow conditions and the roughness of the channel bed. For more information on the theory of power laws for flow resistance see Chen (1991).

For this version of TRANSECT, bottom-track velocity data from the ADCP must be valid for the moving-vessel discharge calculation to be correct. The discharge profile plot in the ACQUIRE and PLAYBACK modes displays the depth to which TRANSECT is measuring discharge for the current ADCP ensemble. The TABULAR submenu shows the discharge value and its corresponding depth.

We begin with a discussion of the moving-vessel method of determining discharge using an ADCP. We then discuss how TRANSECT implements this method and determines the size of the top, bottom, and middle water layers. Table F-1 lists several terms used throughout our discussion. The explanations presented here assume the ADCP is looking down, so *first* implies *shallowest* and *last* implies *deepest*.

Table F-1. Discharge Calculation Terms

Term	Definition
Δt	Time difference between successive ensembles.
BtmQ	Estimated discharge for the unmeasured data at the bottom of the profile.
$*D_a$	Depth cell (bin) size, or the length of the range gate. Each range gate corresponds to a depth cell. The ADCP constructs a profile from a series of range gates or depth cells.
D_{ADCP}	Depth of the ADCP transducer face from the water surface.
$*D_b$	Blank beyond transmit.
D_{LG}	Depth of the last good bin (i.e., the last bin in middle water layer).
D_{LGmax}	Depth of the last *possible* good bin.
D_{total}	Depth to the bottom (i.e., the channel bed).
D_{avg}	Averaged measured depth from the ADCP beams (not including D_{ADCP}).
$*D_o$	Lag between transmit pulses or correlation lag.
$*D_p$	Transmit pulse length. D_p is the length of a single transmit pulse. Broadband systems transmit two or more pulses. If the pulse is coded, this is the total length of one coded pulse, not the length of a single element.
$*D_{top}$	Depth of the center of the first bin.
MidQ	Discharge computed for the middle of the profile from ADCP velocity and bottom-track data.
$*N_p$	Number of transmit pulses.
TopQ	Estimated discharge for the unmeasured data at the top of the profile.
X	Cross-product computed from ADCP data (see ¶F-1.2)
X′	Synthetic cross-product computed from the power-curve fit

*NOTE: THESE DATA ARE DIRECTLY OUTPUT BY THE ADCP.

F-1.1. DETERMINING MOVING-VESSEL DISCHARGE AND THE CROSS-PRODUCT. The moving-vessel method for measuring total discharge using an ADCP is computed by transecting a channel from bank to bank and accumulating the discharge for each ensemble (see Figure F-1). The general equation for determining total channel discharge (Q_t) through an arbitrary surface (*s*) is (Simpson and Oltmann, 1990; Gordon, 1989):

$$\iint_s V_f \cdot n \, ds \qquad \textbf{(Eq.1)}$$

where: ds = Differential area.
V_f = Mean water velocity vector.
n = Unit vector normal to transect path at a general point.

For a vessel moving across a channel, the area of *s* is determined by the vertical surface beneath the transect path. Because the ADCP measures both vessel motion (ADCP bottom-track velocity) and water velocity, we can re-order the integral above (Eq.1) in the following form.

Let: dz = Differential depth
dt = Differential time
V_b = Mean vessel velocity vector
T = Total transect time
d = Total depth (D_{total})
k = Unit vector in the vertical direction

Then:

$$ds = |V_b| \, dz \, dt \qquad \textbf{(Eq.2)}$$

$$V_f \cdot n = |V_f| \sin(\phi) \qquad \textbf{(Eq.3)}$$

$$=> \quad \iint_s V_f \cdot n \, ds = \int_0^T \int_0^d |V_f| \, |V_b| \sin(\phi) \, dz \, dt \qquad \textbf{(Eq.4)}$$

$$= \int_0^T \int_0^d (V_f \times V_b) \cdot k \, dz \, dt \qquad \textbf{(Eq.5)}$$

Converting the cross-product $(V_f \times V_b) \cdot k$ into rectangular (vessel) coordinates, we get:

$$(V_f \times V_b) \cdot k = F_x B_y - F_y B_x. \qquad \textbf{(Eq.6)}$$

where: F_x = Cross-component of the mean water velocity vector.
F_y = Fore/aft component of the mean water velocity vector.
B_x = Cross-component of the mean vessel velocity vector.
B_y = Fore/aft component of the mean vessel velocity vector.

The values for F_x, F_y, B_x, B_y are rotated to earth coordinates before computing the cross-product above (which does not affect the value of the cross-product). Note that TRANSECT converts these values to earth coordinates before any processing is done. Throughout the remainder of this appendix, we will assign the symbol X to represent the cross-product.

F-1.2. METHODS FOR ESTIMATING DISCHARGE IN THE UNMEASURED TOP/BOTTOM PARTS OF THE VELOCITY PROFILE. There are two methods available in TRANSECT to estimate discharge in the unmeasured top/bottom parts of the velocity profile based on the TOP/BOTTOM DISCHARGE ESTIMATE settings in the CFG file (set in the CALIBRATION menu). The two methods are CONSTANT and POWER.

Constant Method. This is the simplest method of estimating the discharge in the unmeasured parts of the profile. However, this method does not follow accepted hydraulic descriptions of the vertical distribution of horizontal water velocities in open channels, particularly in the bottom water layer near the bottom boundary where the velocity decreases to zero. Simpson and Oltmann (1990), and Gordon (1989), discuss this method. This "straight up and down" method extrapolates the cross-product from the first good bin in the profile to the top (TopQ) or from the last good bin to the bottom (BtmQ). See ¶F-1.6 and ¶F-1.7 for details on how TRANSECT does this.

Power Method. Chen (1991) discusses the theory of power laws for flow resistance. Simpson and Oltmann (1990) discuss Chen's power law equivalent of Manning's formula for open channels (with b = 1/6).

$$u/u^{*} = 9.5\,(z/z_0)^{b} \qquad \textbf{(Eq.7)}$$

where:
- z = Distance to the channel bed.
- u = Velocity at distance z from bed.
- u^{*} = Shear velocity.
- z_0 = Bottom roughness height.
- b = Exponent (1/6).

Combining terms not from the ADCP we get:

$$u = (9.5u^{*}/z_0^{b})z^{b}. \qquad \textbf{(Eq.8)}$$

If we let $a' = (9.5u^{*}/z_0^{b})$, then:

$$u = a'z^{b}. \qquad \textbf{(Eq.9)}$$

For the moving boat discharge calculation, the cross-product (X) is computed from the ADCP velocities (Eq. 6), replacing u in the power law of Eq. 9:

$$X = a''z^{b}. \qquad \textbf{(Eq.10)}$$

For each depth cell, the distance from the channel bed z and the cross-product X are computed by TRANSECT. The next step is to solve for the unknown a'' in the power law of Eq. 10. TRANSECT solves for a'' by setting the antiderivative of the power law equal to the cross-product values integrated over the valid depth range of the profile.

Let: Z_1 = Distance from the channel bed to last (deepest) good bin
Z_2 = Distance from the channel bed to first (shallowest) good bin

The values for Z_1 and Z_2 define the region of the profile with valid ADCP data (see Figure F-2). This is referred to as the middle layer of the profile. Section F-1.4 discusses how TRANSECT determines Z_1 and Z_2.

First, we integrate the ADCP data over the valid depth range.

Let:
$$R_1 = \int_{Z_1}^{Z_2} X(z)\, dz \qquad \text{(Eq.11)}$$

where: dz = depth cell size (D_a).

therefore:
$$R_1 = D_a \sum_{i=Z_1}^{Z_2} X_i \qquad \text{(Eq.12)}$$

Second, use the antiderivative of the power law of Eq. 10 to integrate the power law over the middle water layer:

$$f(z) = a'' z^b \Rightarrow F(z) = a'' \frac{z^{b+1}}{b+1} \qquad \text{(Eq.13)}$$

Let:
$$R_2 = \int_{Z_1}^{Z_2} f(z)\, dz \qquad \text{(Eq.14)}$$

$$= a'' \left. \frac{z^{b+1}}{b+1} \right|_{Z_1}^{Z_2} \qquad \text{(Eq.15)}$$

$$= \frac{a'' \left(Z_2^{b+1} - Z_1^{b+1}\right)}{b+1} \qquad \text{(Eq.16)}$$

Equating the integrals we solve for *a″*:

$$R_1 = R_2 \qquad \text{(Eq.17)}$$

$$D_a \sum_{i=Z_1}^{Z_2} X_i = a'' \left[\frac{Z_2^{b+1} - Z_1^{b+1}}{b+1} \right] \qquad \text{(Eq.18)}$$

$$a'' = \frac{D_a (b+1) \sum_{i=Z_1}^{Z_2} X_i}{Z_2^{b+1} - Z_1^{b+1}} \qquad \text{(Eq.19)}$$

Using *a″*, we can apply the antiderivative of the power law to integrate over the unmeasured regions of the profile at the top and bottom (see ¶F-1.6 and ¶F-1.7).

F-1.3. DETERMINING NEAR-SHORE DISCHARGE. You can use the TRANSECT PLAYBACK menu to estimate the discharge near the shore. TRANSECT uses a ratio-interpolation method for estimating the velocity between the channel bank and the first or last known mean velocity (V_m) in a subsection (ensemble or segment if averaging is ON in PLAYBACK). If we assume a triangular area between the last subsection and the channel bank, an algorithm for estimating the discharge in this near shore area is:

$$Q_{side} = 0.707\ V_m\ L\ d_m\ /\ 2. \qquad \text{(Eq.20)}$$

where: d_m = Depth of the first or last subsection.
L = Distance from the shore to the last subsection.

Again, note that if averaging is ON in PLAYBACK, V_m is the mean velocity for the segment (averaging interval). If averaging is OFF, V_m is the mean velocity for the ensemble. This allows flexibility if there are bad ensembles at the start or end of the transect.

F-1.4. HOW TRANSECT DETERMINES THE SIZE OF THE TOP/BOTTOM/MIDDLE WATER LAYERS. Before computing discharge, TRANSECT must determine the size of the top, bottom, and middle water layers (see Figure F-2). See Table F-1 for term definitions.

TRANSECT uses the center of the first depth cell to find the thickness of the top water layer. To compute the thickness of the top water layer, we start with the depth to the center of the first depth cell, D_{top}.

$$D_{top} = D_{ADCP} + D_b + ((D_p + D_o + D_a)\ /\ 2) \qquad \text{(Eq.21)}$$

For the total water depth, we use the average of the beam depths.

$$D_{avg} = \text{Average of four beam depths} \qquad \text{(Eq.22)}$$

TRANSECT computes the last good bin depth from D_{avg} by determining the depth of noise interference from the acoustic side lobes, adding the depth of the transducer face from the surface, and adding a thickness that depends on the transmit pulse sequence.

$$D_{LGmax} = (D_{avg}\cos(\theta) + D_{ADCP})\ -\ ((D_p - D_o)\ /\ 2) \qquad \text{(Eq.23)}$$

D_{LGmax} is the last possible depth of a good bin. D_{LG} is the depth of the lowest bin that is above D_{LGmax}. The position of the last good depth cell (D_{LG}) gives us the starting depth of the bottom water layer. The valid ADCP velocity data in depth cells starting at D_{top} and ending at D_{LC} are used to calculate the middle layer discharge (MidQ). TRANSECT obtains the distance to the bottom (D_{total}) as:

$$D_{total} = D_{avg} + D_{ADCP} \qquad \text{(Eq.24)}$$

From the preceding we can define the boundaries of the water layer (Fig. F-2):

$$Z_1 = D_{total} - D_{LG} - D_a/2 \qquad \text{(Eq.25)}$$
$$Z_2 = D_{total} - D_{top} + D_a/2 \qquad \text{(Eq.26)}$$
$$Z_3 = D_{total} \qquad \text{(Eq.27)}$$

The water layer thickness follows:

$$\text{Top layer} = Z_3 - Z_2 \qquad \text{(Eq.28)}$$
$$\text{Middle layer} = Z_2 - Z_1 \qquad \text{(Eq.29)}$$
$$\text{Bottom layer} = Z_1 \qquad \text{(Eq.30)}$$

F-1.5. HOW TRANSECT CALCULATES MIDDLE LAYER DISCHARGE (MidQ). TRANSECT calculates the middle layer discharge over the range determined by the middle water layer thickness (Eq.29). For each bin, TRANSECT computes the discharge in that bin using the cross-product (Eq.6) and the time difference between successive ensembles.

$$Q_i = X_i \, \Delta t \, D_a \qquad \text{(Eq.31)}$$

where: i = Bin number.
Q_i = Discharge in the i^{th} bin.

The value of Q_i is that value displayed in the TABULAR submenu at its corresponding depth. TRANSECT determines the discharge for the middle layer by summing all the discharges from the individual bins.

$$MidQ = \sum_{i=1}^{N} Q_i \qquad \text{(Eq.32)}$$

where: i = The first good bin. If the first bin has bad data, TRANSECT increments i until it finds good data. If TRANSECT does not find good data, it does not calculate discharge for the ensemble.
N = The number of the bin just above the bin that D_{LG} intersects.

F-1.6. HOW TRANSECT ESTIMATES TOP LAYER DISCHARGE. There are two ways to compute the top layer discharge estimate based on the setting of TOP DISCHARGE ESTIMATE in the configuration file. The two options are CONSTANT and POWER. Paragraph ¶F-1.2 outlines these methods.

Constant Method. TRANSECT estimates the discharge for the top water layer by extrapolating the value of the cross-product in the first good bin to the surface. This method extrapolates data in a straight line to the surface.

$$TopQ = X_{FG} \, \Delta t \, (Z_3 - Z_2) \qquad \text{(Eq.33)}$$

Power Method. TRANSECT estimates the discharge for the top water layer by integrating the power law of Eq. 10 over the top water layer and multiplying by Δt (see Figure F-2):

$$TopQ = \Delta t \, a'' \int_{Z_2}^{Z_3} z^b \, dz \qquad \text{(Eq.34)}$$

$$= \frac{\Delta t \, D_a \, (Z_3^{b+1} - Z_2^{b+1}) \sum_{i=Z_1}^{Z_2} X_i}{Z_2^{b+1} - Z_1^{b+1}} \qquad \text{(Eq.35)}$$

F-1.7. HOW TRANSECT ESTIMATES BOTTOM LAYER DISCHARGE. There are two ways to compute the bottom layer discharge estimate based on the setting of BOTTOM DISCHARGE ESTIMATE in the configuration file. The two options are CONSTANT and POWER. Paragraph ¶F-1.2 outlines these methods.

__Constant Method__. TRANSECT estimates the discharge for the bottom water layer by extrapolating the value of the cross-product in the last good bin (X_{LG}) to the bottom. This method extrapolates data in a straight line to the bottom.

$$BtmQ = X_{LG}\,\Delta t\,Z_1 \qquad \text{(Eq.36)}$$

__Power Method__. TRANSECT estimates the discharge for the bottom water layer by integrating the power law of Eq. 10 over the bottom water layer and multiplying by Δt (see Figure F-2):

$$BtmQ = \Delta t\ a'' \int_0^{Z_1} z^b\,dz \qquad \text{(Eq.37)}$$

$$= \frac{\Delta t\ D_a\ Z_1^{b+1} \sum_{i=Z_1}^{Z_2} X_i}{Z_2^{b+1} - Z_1^{b+1}} \qquad \text{(Eq.38)}$$

F-1.8. REFERENCES. The following references were used in preparing this section.

Chen, Cheng-Lung (1991). "Unified Theory on Power Laws for Flow Resistance." Journal of Hydraulic Engineering, Vol. 117, No. 3, March 1991, 371-389.

Simpson, M. R. and Oltmann, R. N. (1990). "An Acoustic Doppler Discharge Measurement System." Proceedings of the 1990 National Conference on Hydraulic Engineering, Vol. 2, 903-908.

Gordon, R. L. (1989). "Acoustic Measurement of River Discharge." Journal of Hydraulic Engineering, Vol. 115, No. 7, July 1989, 925-936.

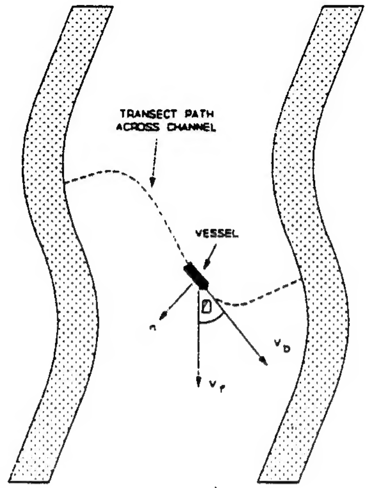

Figure F-1. Sample Transect Across a Channel

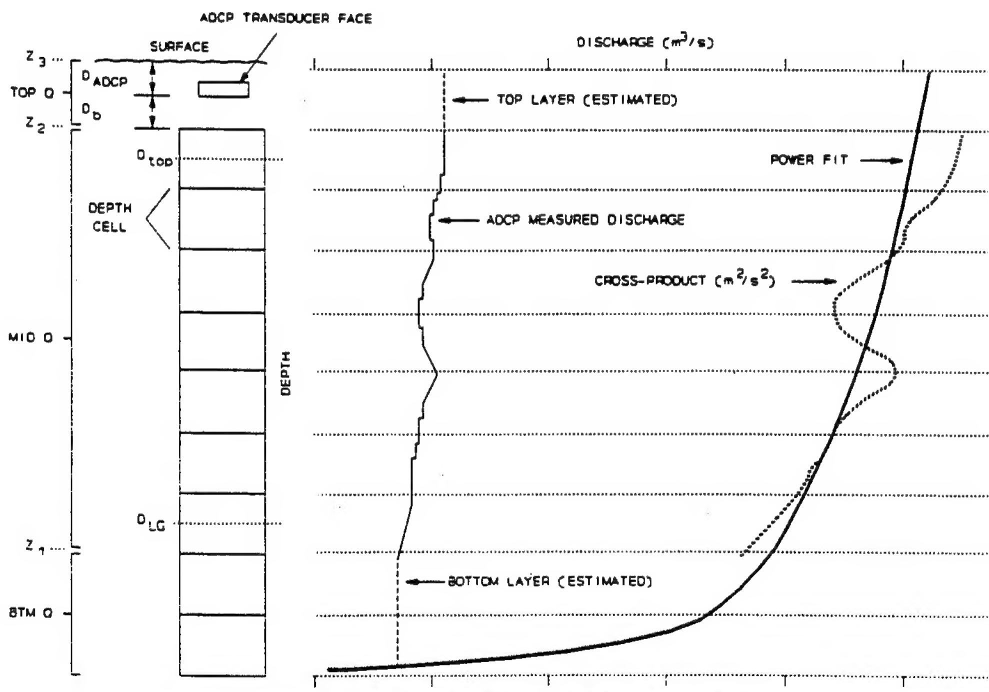

Figure F-2. Sample Plot of Discharge Data

NOTES

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13. ABSTRACT *(Maximum 200 words)*

The Vicksburg District monitors multiple gaging stations along the Mississippi River using conventional methods. The records for these stations date back for many years giving the Corps an excellent understanding of how the river discharge reacts to spring thaws and large-scale storm events. These records provide the Corps with information to maintain and operate the navigable waterways along the Mississippi. As technology develops, the Corps is always eager to incorporate new technology into its operating plans, but not without extensive testing.

The Hydraulics Laboratory at the Waterways Experiment Station was contracted by the Vicksburg District to evaluate the present discharge measurement technique against a new technique using an Acoustic Doppler Current Profiler. A testing plan was developed to compare these two techniques over two different flow conditions. The focus of this report is to present the data from both exercises, describing how the two methods calculate discharge through a cross section and identifying possible sources of error.

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